# MANUAL OF GUNNERY

FOR

# HER MAJESTY'S FLEET.

1880.

BY AUTHORITY OF THE LORDS COMMISSIONERS OF THE ADMIRALTY.

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# CONTENTS.



## ORGANISATION.

### CHAPTER I.

### QUARTER BILL AND FIGHTING ARRANGEMENTS.



## GUNNERY.

### CHAPTER II.

### GUNS.

## CHAPTER III.

## CARRIAGES AND SLIDES.



## CHAPTER IV.

## POWDER.



## CHAPTER V.

## MOTION OF PROJECTILE.



## CHAPTER VI.

## ROTATION AND RIFLING.

## CHAPTER VII.

## ACCURACY OF FIRE.



**Naval Gunnery.**

## CHAPTER VIII.

## ACCURACY AT SEA.



## CHAPTER IX.

## CONCENTRATING AND THE DIRECTOR.



## CHAPTER X.

## ASCERTAINING THE DISTANCE OF AN OBJECT AT SEA.



## CHAPTER XI.

## SYSTEMS OF FIRING.



## CHAPTER XII.

## PENETRATION OF ARMOUR.

## CHAPTER XIII.

## EFFECTS OF FIRE.



**SHIPS AND ARMOUR.**

## CHAPTER XIV.

## ARMAMENT.



## CHAPTER XV.

## SHIPS.



## CHAPTER XVI.

## ARMOUR.

## MISCELLANEOUS.

### CHAPTER XVII.

### MACHINE GUNS.



### CHAPTER XVIII.

### AMMUNITION.



### CHAPTER XIX.

### GUN-COTTON AND DYNAMITE.



### CHAPTER XX.

### MAGAZINES AND SHELL-ROOMS.

## CHAPTER XXI.

### STOPPING LEAKS.



## CHAPTER XXII.

### RETURNS, EXAMINATION, AND PRESERVATION OF GUNS, CARRIAGES, AND SLIDES.



## CHAPTER XXIII.

### TRAINING MEN AND TARGET PRACTICE.



## CHAPTER XXIV.

### HASTY INTRENCHMENTS, FIELD FORTIFICATIONS, AND CAMP DUTIES.

## RANGE TABLES.



## APPENDIX.



## INDEX.

# INTRODUCTION.

A remarkable increase in the knowledge of facts connected with Gunnery has taken place within the last few years. This has made it evident that the powers of ordnance can be greatly developed, and will necessitate a complete revolution in our armaments, entailing great changes in the guns, systems of mounting, and ammunition. Present state of gunnery.

Besides the question of actual armaments, other matters relating to naval gunnery, such as firing at sea, &c., are also in a tentative and undeveloped stage. In view, therefore, of these changes and of the wide differences of opinion existing on many points, even among those best qualified to judge, this work assumes necessarily to a certain extent the character of a treatise. Design of work.

The object aimed at has therefore been to explain principles, illustrating them by typical examples taken from various sources not confined to service forms, so that officers may be able to see for themselves the direction in which the various improvements and changes are now tending.

Every endeavour has been made to state the arguments for and against any particular theory, omitting all expressions of mere opinion, and only drawing conclusions when the evidence seemed decisive.

The work has been divided into— Division into parts.

Organisation,
Gunnery,
Naval gunnery,
Ships and armour,
Miscellaneous,

as offering the most convenient arrangement.

The preliminary chapter in the Gunnery Manual for 1873 served as the basis for the organisation; but the great changes, which have been introduced into the arrangements of the new ships, necessitated some alterations and considerable additions. Further experience will probably lead to modifications, and therefore many of the details are only given as a guide, much being left to individual discretion. Organisation.

The portion of the work devoted to gunnery proper has been compiled from various sources. Gunnery.

The chapter on "Guns" is derived to a large extent from the "Treatise on Gun Construction," especially as relates to Guns.

Guns.

our own ordnance; but the writings of Holley, Longridge, and others have also been consulted.

The principles governing the construction of ordnance were alluded to in the Manual of 1873, and in view of the unsettled state of this question it is considered advisable to explain them somewhat more fully in this edition.

Full details of the most prominent systems of breech-loading have been given, as the proposed introduction of breech-loading guns makes this of great importance, the system to be adopted for the service guns about to be manufactured not yet being decided, and the necessary information not existing in any English work.

Mounting of ordnance.

The Manual of 1873 did not contain any information relative to the mounting of ordnance, but the importance of the subject necessitated its discussion in this edition. The chapter is necessarily very incomplete, as this question has never been fully treated of, and is far from being worked out. It is hoped that sufficient has been said to draw attention to the changes which must necessarily take place in this direction, both in order to increase the facility of working, and as a necessary consequence of the very heavy charges now being introduced.

Powder.

The Manual of 1873 contained a short account of the action of gunpowder, which the great advance during the last ten years has rendered it necessary to recast and greatly amplify. The chapter on this subject is in the main a reproduction of the work of Captain A. Noble and Professor Abel, and as upon a knowledge of the action of fired powder depends a correct appreciation of all recent and future advances in gunnery great stress has been laid upon the subject.

Motion of projectiles.

The experiments of the Rev. F. Bashforth necessitated an entire re-arrangement of the chapter on the "Motion of a Projectile," which has been compiled from the works of Mr. Bashforth, Major Sladen, R.A., and W. D. Niven, Esq., M.A. It was considered unadvisable to introduce any investigations requiring a knowledge of the Calculus, so that for a full treatment of the subject officers are referred to the above works.

Rotation and rifling.

The question of rotation and rifling is to a certain extent in the empirical stage. The chapters on this subject are derived principally from the Treatise on Ammunition, and the works of Major Sladen, R.A., and Professor Greenhill.

Naval gunnery.

Under the head of Naval Gunnery have been discussed questions relating to firing at sea, both as regards method of firing and effect produced. A portion of this was contained in the Manual of 1873, but it has now been much

amplified. The chapter on "Accuracy" at sea is not exhaustive, but is capable of great development. This subject has lately been discussed in some of the continental *Magazines*. **Accuracy at sea.**

The chapter on "Systems of Firing" is entirely suggestive. **Systems of firing.**

The method of obtaining distances is taken from Admiral Ryder's well known work.

The chapter on the "Effects of Fire" has been compiled from various sources, such as the Proceedings of the Director of Artillery, the Prussian Drill Regulations, &c. This has been made as complete as possible, as it is considered that for a naval officer its importance cannot be over-rated. **Effects of fire.**

The tables giving the details of the comparative powers of service and other ordnance are to a certain extent incomplete, but contain fuller information than has hitherto been within the reach of a naval officer, and will be found to afford valuable means of comparing different systems of armament. **Table of ordnance.**

The chapter on "Armament" only deals with the broad principles on which the solution of this question depends.

As a knowledge of the leading particulars of the various classes of ships of our own and foreign navies is both useful and interesting to naval officers, and only to be found scattered through various works, a part of the Manual has been devoted to "Ships and Armour." The scope of the work would not admit of the insertion of more than a short description of the more prominent types, with diagrams and tables, the latter being in many cases incomplete. **Ships and armour.**

In the preparation of the tables, &c. great assistance has been derived from the works of King, Dislere, Marchal, from the Carnet de l'officier de Marine, and the Almanach für die K. K. Kriegsmarine.

In the "Miscellaneous" part a chapter on "Machine Guns" has been introduced, as their developement and the great part which they will probably take in naval war makes it desirable that all officers should be acquainted with their leading features. **Miscellaneous.**

A chapter on ammunition has been introduced, because the official Treatise on Ammunition is not in the possession of every officer, so that many would necessarily have nothing to refer to, if this were not included. It is chiefly from the above named work.

The remainder of this part contains matter which was in the Manual of 1873, but is re-arranged and corrected. Three additions have however been made, namely, the chapters on "Magazines," "Stopping leaks," and "Examination of Guns, &c.," which seemed to be requisite.

Fortification. Lastly, as in the Manual of 1873, a chapter on field fortification has been added, in which the parts most useful to a naval officer have been amplified. In future editions, this chapter will probably find a place in the "Manual of Field Exercise."

Range tables. Improved range tables are in course of preparation, but it was found impossible to complete them in time for insertion, the old tables for projectiles without gas-checks have therefore been retained.

The following matters contained in the Manual of 1873 have been omitted from the present work.

1. Details of examinations, which are now fully given in the revised Admiralty Instructions and Addenda.
2. All relating to the landing party, as this subject is fully treated in the Manual of Field Exercise.
3. Remarks on Diving, which are issued in a separate form.
4. Instructions and details relating to torpedo stores and fittings, for which officers can now refer to the Torpedo Manuals.

# ORGANISATION.

## CHAPTER I.

### QUARTER BILL AND FIGHTING ARRANGEMENTS.

#### ARRANGEMENT OF QUARTERS.

**Division into quarters.** The first step towards making out the quarter bill is to divide the armament into quarters, and to number or name the guns, so that they may be distinguished from each other, without reference to their size.

**Heavy guns.** The guns should be arranged in quarters in such a way that the Officer in charge may be able to exercise a personal supervision over all guns, therefore with heavy guns* there should be not more than three or four in the quarters, and these should be, if possible, all visible from some central point.

Where there are sufficient heavy guns together on each side of a deck to form a division, they should be so arranged in order that the Officer in charge may be able to confine his attention to one side of the ship.

Where, however, a small number of guns are separated from the rest, either by armoured bulkheads or by being placed at some distance, it will be necessary to form a division comprising guns on both sides of the ship.

**Light guns.** In ships armed with light guns on the broadside, the quarters should consist of a certain number on both sides, as either or both sides have to be worked by the same men.

It is frequently necessary in arranging the quarters to consider the supply of powder, as where it can be avoided guns at the same quarters should not be supplied from different magazines.

In turret ships each turret will form a quarter by itself.

**Numbering the guns.** When a separate crew is to be stationed to each gun, the guns will be numbered odd on the starboard side, and even on the port side, commencing from forward in each battery or on each deck; when they are to be worked with half crews they will be numbered from forward, aft on each side of the deck, the odd numbered guns on the starboard side and the even numbered guns on the port side being known as the left guns, and the others as the right guns.

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* *Note.*—By "heavy guns" are understood guns of 4½ tons and upwards.

Guns mounted independently, as for instance, bow and stern guns, will be given names depending on their position.

Guns in turrets will be known as the right or left gun of each turret.

## STATIONING THE OFFICERS.

**Executive Officer.** The Executive Officer should, under the Captain, exercise general supervision. He should, however, generally be in a position in which he can communicate immediately and personally with the Captain, and be acquainted with his plans and with the movements of the ship and enemy, before and during the action, so as to be prepared to assume the command at any moment.

**Gunnery Lieutenant.** The Gunnery Lieutenant should also assist the Captain in general supervision. He should have charge of the directors, and where there is no Torpedo Lieutenant of the Whitehead torpedoes, but to each of these duties Officers thoroughly instructed and frequently exercised should be stationed, to provide for the case of the Gunnery Lieutenant being required elsewhere.

**Torpedo Lieutenant.** The Torpedo Lieutenant should be left free to look after the torpedoes and the electrical communications.

**Below gun deck.** In large ships one Lieutenant carefully selected should be placed in charge of the whole of the ship below the battery deck, with the exception of the engine room. He will be responsible for the supply of ammunition and should have under him an executive Officer (a Sub-Lieutenant if available), the Engineer Officers stationed with the fire brigade, and the

**Gunner Carpenter** Gunner and the Carpenter, the former attending to the magazines and shellrooms, and the latter to fire arrangements and damages to the hull.

In small ships a Sub-Lieutenant, or the Gunner if no Sub-Lieutenant is available, should be detailed for this duty.

**Officers of quarters.** The other Lieutenants and Sub-Lieutenants should be stationed to the quarters, one as a rule being given charge of the detached parties on the upper deck.

In turret ships each turret should be under the command of a Lieutenant, assisted by a Sub-Lieutenant in the turret room.

**Navigating** The Navigating Officers should assist the Captain in conning the ship.

**Boatswain.** The Boatswain should have charge of the riggers under the Officer of the upper deck.

**Sub-Lieutenants and Midshipmen.** The Sub-Lieutenants and Midshipmen should be distributed to the several quarters, a certain number of the latter being stationed to the voice tubes, and to convey orders, &c.

One or more Sub-Lieutenants or Midshipmen, according to the number available, should be stationed to the signals.

A Sub-Lieutenant, or trustworthy Midshipman, should be stationed aloft to observe and pass down the distance of the enemy.

When machine guns are mounted in tops a Sub-Lieutenant or Midshipman should be in charge.

The Officers of Marines should be stationed according to the distribution of their men. Marine Officers.

The Torpedo Engineer with his staff should attend to the charging columns and air pumps. Other Officers.

The other Engineer Officers should be stationed under the Chief Engineer, according to the special requirements of the ship.

The non-executive Officers, except the Engineers and carpenter, should attend to the wounded.

## Stationing the Ship's Company.

A gunner's mate should be in charge of each magazine. If there are more than are required for this duty, the others should be put in the most important special stations according to their qualifications. Special stations.

In large ships, besides the gunner's mates, at least two seamen gunners should be stationed in each magazine, and a trustworthy petty officer in each shell room.

Where Whitehead torpedoes are carried, the principal men stationed to them should be most carefully selected from the torpedo men; and the torpedo instructor with two or three steady torpedo men should have charge of the magazine.

A seaman gunner petty officer with assistants should be stationed to superintend the supply of fuzes.

Good well-trained seamen gunners should be selected for the charge of the machine guns.

In turret ships great care should be taken in the selection of the captains of the turrets; gunner's mates may be stationed to perform this duty, provided they are good shots.

The Nos. 1. at the guns should always be good shots, and if possible seamen gunners, the best men being selected for the directing guns; the remainder of the seamen gunners should be stationed to the more important numbers. Guns' Crews.

The remainder of the guns' crews, should be composed of men taken as much as possible from the different parts of the watch bill both as regards parts of the ship and boats, avoiding stationing petty officers to guns at which the Nos. 1. are their subordinates.

**Gun's crews.** As a rule 1st class petty officers who are not seamen gunners should not be stationed to guns.

In armoured ships crews should be stationed to the light guns on the upper deck. If the complement will not admit of special crews, the riggers and boys will be available for this duty.

Guns' crews should be allotted as follows :—

To each turret gun, according to the fittings of the turret.

| | | |
|---|---|---|
| *Broadside Guns.* | To each 12-inch gun<br>„ 11-inch gun<br>„ 10-inch gun | - 17 men and 2 powdermen. |
| | To each 9-inch gun<br>„ 8-inch gun | - 15 men and 1 powderman. |
| | „ 7-inch $6\frac{1}{2}$-ton gun | - 14 men and 1 powderman. |
| | „ 7-inch $4\frac{1}{2}$-ton gun | - 10 men and 1 powderman. |
| | To every two 64-pounders | - 14 men and 1 powderman. |
| | „ 40-pounders | - 12 men and 1 powderman. |
| | „ 20-pounders | - 8 men and 1 powderman. |
| | To each Nordenfelt gun - | - 5 men. |
| | „ Gatling gun - | - 5 men. |

A revolving 7-inch gun will require at least 3 men in addition.

When 64-pounders or 40-pounders are mounted as revolving or chase guns full crews should, if the complement admit of it, be stationed to them.

The odd numbered guns are manned by the starboard watch, and the even numbered guns by the port watch.

In turret ships having two turrets it will be found advisable to give one turret to each watch.

**Marines.** The marines, whether artillery or infantry, are to be stationed at the guns in such a manner as will least impair the efficiency of the arrangements for action in case the marines should be landed, the marine artillery men being given the most important numbers.

**Marine small-arm men.** A certain number of infantry, depending on the size and armament of the ship, should be told off as marine small-arm men. When machine guns are mounted round the upper deck there is less need for marines as small-arm men, and they are more wanted at the guns.

**Powdermen.** Extra powdermen in such numbers as are required by the fittings of the ship and the size of the guns, should be stationed to keep up the supply of powder from the magazine scuttles to the quarters.

Where the charges are too heavy for boys men are to be stationed to this duty.

A certain number of the best rifle shots among the seamen should be selected and stationed in the tops; in large ships, at least six in the fore and main, and four in the mizen tops. **Top riflemen.**

When a machine gun is mounted in the top these men will work it, falling back on their rifles in case of accident to the gun.

The riggers should consist of men taken from different parts of the watch bill, but are on no account to include a seaman gunner, unless he hold the ratings of chief boatswain's mate or chief captain of the forecastle. About three for every 100 of the complement may be considered the average number for this duty. **Riggers.**

The men required for the supply of powder in addition to the seamen gunners and powdermen mentioned above, may be taken from the idlers, band, &c., the best men being stationed in the magazines and handing rooms. **Magazine.**

A Ship's Corporal or an Artificer Petty Officer should be stationed at the supply scuttle to superintend the issue of powder, and one in charge of each handing room.

A certain number of men, chosen in the same manner as the magazine men, should be stationed in the shell room to get out and sling projectiles. **Shell room men.**

A sufficient number of men, according to the fittings of the ship, should be stationed to supply projectiles from the racks in the compartments below, and from the shell rooms, to the places whence they are whipped up. This party should be formed from the idlers, and such seamen and boys as are not otherwise stationed. **Projectile party.**

The carpenters under the Carpenter, and a portion of the stokers under an Engineer Officer, should form the fire brigade, special men being stationed to attend the water-tight doors. **Fire brigade.**

A party should be stationed to assist the men at the torpedo magazine to whip up and transport the torpedoes. **Whitehead party.**

The armourers should be stationed at the quarters to assist in replacing any disabled gear at the guns, and to look after the electric wires; should there be more than are required for these duties they may assist in fitting fuzes. **Armourers.**

Non-commissioned officers of light infantry stationed at the quarters should supply tubes to the guns, and distribute small-arm ammunition. **Miscellaneous.**

Men are required for the following duties in addition to those already detailed:—

Miscellaneous. Wheel, relieving tackles, signals, buglers, orderlies, store-rooms, light rooms, magazine and shell-room air pumps, small-arm magazine, water supply to gun decks, care of wounded, and other duties dependent on the fittings of the ship.

## Issue of Arms.

Rifles. The whole of the rifles are to be issued.

All the upper deck guns' crews, top riflemen, and boats' crews (except coxswains and bowmen), should be armed with rifles; the remainder being divided among the battery guns' crews.

In some ships it may be necessary to arm the smartest boys with rifles.

If the riggers are stationed to light guns they should be armed with cutlasses and pistols, but if not they should, if possible, have rifles.

Cutlasses. Cutlasses are to be distributed to all the remainder of the seamen, observing that coxswains and bowmen of boats, instructors, buglers, signalmen, helm and leads men, &c., and the field guns' crews should be armed with cutlasses.

Any cutlasses remaining may be told off to the idlers or stokers belonging to the detached parties for landing, and to boys not having rifles.

Pistols. The pistols should be numbered, and should all be kept together in some convenient place, being under charge of the armourers.

It will usually be more convenient to cause the armourers to clean them, as, owing to the variety of circumstances under which they are issued, it will be found impracticable in most cases to keep a pistol for the use of any individual man.

For quarters pistols are told off, as far as they will go, for instructors, signal party, helm and leadsmen, voice tube men, Nos. 1 and 2 at guns, and in some cases for riggers.

This will generally be found to dispose of all the pistols, but should there be any over they may be distributed to men at guns who have no rifles.

For manning and arming, pistols will be taken by the coxswains and bowmen of boats, and others as told off in the Drill Book.

For landing, the field guns' crews take pistols, and the remainder should be issued according to the instructions in Manual of Field Exercise.

The pikes are not issued, but a certain number should be kept in convenient places on the upper deck, and the remainder made up in bundles ready to be passed up at quarters, or into the boats for manning and arming. **Pikes.**

The tomahawks are also not issued, but some should be kept in a rack together with their frogs, so that they may be ready for use by the riggers at quarters, or by the fire brigade at any other time. The remainder, like the pikes, should be made up in bundles for the larger boats. **Tomahawks.**

It is advisable that the men should as far as possible retain the same rifles and cutlasses that are first issued to them, and therefore it will be found impracticable to confine any special numbers of these arms to particular duties.

The reserve ammunition pouches for rifles, water bottles, and haversacks, should not be issued unless required. **Reserve gear.**

## Preparation for Battle.

### *General Remarks.*

The instructions given below are not to be considered imperative, they are inserted for the information of Officers, and agree generally with the orders which have been given to the Channel and Mediterranean fleets of late years, but each Officer in command of a ship or squadron should exercise his discretion with reference to all the circumstances in carrying them out. **Instructions not imperative.**

Many of the preparations mentioned below may be made when war is declared, and spars, sails, and much gear would *probably* be landed. **Early preparations.**

The proper preparation of a ship for battle is a most difficult and important question, and many disputed points cannot be settled without the experience gained by actual warfare.

In every ship stations are to be carefully prepared, showing the actual duties of every one on preparing for battle. In many cases it will be necessary to carry out experiments to ascertain the best manner of arranging protection, &c., and of stowing away gear. **Stations.**

### *On Deck and Aloft.*

When ships are ordered to prepare for action, and time admits, preparations should be made both below and aloft.

Top-gallant masts and yards, and flying and studding-sail booms should be sent on deck and stowed on the booms or **Spars.**

Spars. where they would be least in the way; if left up and down the masts they must be securely lashed. Gaffs may either be sent down, or securely slung aloft. In all ships the jib booms should be run close in, and if the bowsprit is movable it should be got in also.

The head gear should be triced up clear of the fire of the bow guns. If there is room to stow away the cross jack and mizen topsail yard, and if they happen to be over the bridge or other place usually occupied by the Officers, or over guns, it may be advantageous to send them down. The crossjack yard, if lashed just above the netting, may, however, be found useful for clearing the screw.

Ropes. All ropes which are not required should be unrove, and stowed with all inflammable and superfluous gear below the water line, especially those, such as the main sheets, which are likely to foul the screw. If there be time mantlets may be made from available ropes.

Sails. The mainsail should be unbent.

The question whether the other sails should be unbent will depend on whether the capacity of the ship for manœuvring under sail would counterbalance the disadvantage of their possibly catching fire. If they are not unbent they should be well wetted.

At least one sail should be on deck for use in stopping leaks (*see* p. 415).

Yards. Short jeers should be rove, the yards braced sharp up, the standing part of the braces toggled, the weather braces being not too taut and frapped in to the backstays.

Rigging, &c. Preventor stays should be got on, stays and backstays snaked, hawsers passed round the rigging ready for frapping in a wreck, and grapnels placed on each quarter to prevent the screw being fouled.

Anchors should be lashed, bower cables and gangers unbent and stowed away if in the open sea, or triced up if in pilotage waters and they interfere with the fire of the guns.

Spare steering gear should be prepared, and rudder pendants partly cleared away.

Boats' davits should be topped up or turned in, boom boats clear for hoisting out, and all boats uncovered.

Protection. If no special protection is supplied, the bridges, the wheel, and the fore part of the poop, if necessary, should be protected by hammocks, wetted sails, &c.; awnings may also often be spread with advantage over these parts.

Attention should also be directed to the protection of the steering gear.

To protect from raking fire hawsers may be flaked across the decks.

Fittings in various parts of the upper deck should be provided by means of casks, planks, mess tables, &c., for the marine small-arm men to fire from over the netting, and for the other riflemen when ordered. It would be desirable that these should be permanently fitted. **Rifle platforms.**

Reeving lines for collision mats should be got into place.

All prominent white marks on the outside should be painted out. **Miscellaneous.**

Bulkheads which may interfere with the necessary movements during action must be cleared away.

All glass skylights and windows should be removed, gratings put on hatchways, and all iron or brass railings unshipped and rope substituted.

Signal halliards should be rove from crosstrees, &c., and led down under cover.

The electric firing gear should be tested.

If the projectiles have not been gauged lately as many as possible should be examined.

In the case of an expected night action, in dry weather, it may be found of great service to whitewash the decks, gun carriages, and everything that has to be handled. **Night action.**

*Gun Deck.*

The mess tables, stools, sashes, mess utensils, and everything stowed over the guns should be put down below in selected places. **Movable gear.**

Jacob's ladders should be fitted for all the hatchways near the guns, and the standing ladders stowed below.

All movable gear should be removed from the ship's side; all shell gratings shipped; boats' shell boxes, if on gun deck, put in shell room; and the capstan bars, and all pump gear which is not kept shipped at quarters, put in some known place clear of the guns.

All tubes, spare gun gear, and other gear such as loading and port tackles, kept below, which may be required and which can be easily placed, should be brought up and distributed in convenient places which should be well known to the officers and men. **Spare gun gear.**

Spare breechings, tackles, and hoses not in use, if stowed over the guns, should be taken down from overhead, and placed amidships.

In central battery ships gear if not in the way may be left in its place on the deck outside the battery; and this part of

the ship may also be utilised for the stowage of gear from the upper deck and battery. The battery doors should be examined.

*Below Gun Deck.*

Stowage of gear.

The greatest care must be exercised in selecting the places for stowage of sails and other gear from the decks, so as not to interfere with the supply of powder, &c., and so that the wings may be kept clear. It will often be necessary for this purpose to move bag racks, &c.

The watertight doors should be examined.

Hawsers, tackles, &c., and generally all gear which will be required on deck, should be seen clear.

## Action.

Call for action.

On the call for action every one repairs at once to his allotted station, the marine small-arm men and top riflemen taking their arms with them.

The Gunner obtains the keys of magazines and shell rooms and gives them to the petty officers in charge; he then sees that the lights are lighted, everything in working order, and the powder passed up, both the supply and return scuttles being used for the first supply.

The powdermen receive the powder and take it to the guns, which are at once to be cast loose, loaded, and run out close to the port, the latter being lowered.

Charge and projectile.

In armoured ships guns as a rule are to be loaded with battering charge and Palliser shell, and in unarmoured ships with full charges and common shell filled. The above charges are those to be kept in the ready racks.

Should it be desired to load with a different charge or projectile to that named above, the "Still" must be sounded, and the order given.

Guns left secured.

In ships where the guns are secured in the loading position it is recommended that the flaps should not be taken up, or in the case of permanent rollers that the rear screws should be kept on, until after arms and stores are provided. When it is necessary to train for loading, this cannot be done, but great care should be taken to see that the brakes and pauls are secured before leaving the guns.

Small-arm ammunition.

A supply of rifle and pistol ammunition should be passed up ready for distribution on the decks by men specially stationed, and reserves must also be placed at fixed stations on the upper

deck. An ample supply of pikes should also be placed at the boarders' muster places. Small arm ammunition.

Ammunition should be served out at once to the marine small-arm men and top riflemen; and after the arms are provided, to the remainder of the quarters.

Machine gun ammunition should be passed up at once, and hoppers or drums filled by the men stationed.

Riggers provide luffs and all gear necessary for frapping in rigging and clearing away wreck of spars, &c.; also grapnels for clearing the screw, tomahawks and axes for cutting away wreck, &c., and collision mats and gear, being aided, if necessary, in this latter duty by other detailed parties. Riggers.

After everything is in place, all gear provided and rigging frapped in, they will, if not stationed to light guns, fall in with their arms at some allotted station on the upper deck.

Top riflemen provide arms, ammunition, and top screens, then go into the tops and place themselves in the best positions for firing, keeping themselves concealed, and arranging any protection with which they may be provided. Top riflemen.

In the tops where machine guns are mounted, some men must be detailed to go aloft and pay down a tackle, whilst the remainder provide gear and prepare the gun.

Helmsmen, signalmen, &c., provide their arms and repair to their stations, where they should make the requisite preparations. Helm.

The relieving tackles should be hooked to the ship's side and got ready for use, and fighting wheel ropes prepared for bringing to, in case of accident to the other steering gear.

A party of men must be trained to fill up casualties in steering party or to work relieving tackles. These men should have other stations when not required at the helm.

Orderlies, buglers, and men stationed at voice tubes, being required immediately, should repair to their stations without delay; if necessary their arms being afterwards provided for them.

Fire brigade should connect hoses to and rig all pumps below the gun deck, and any on the gun deck which are quite clear of the guns and the supply of ammunition. Fire brigade.

The Carpenter is responsible that the pump suctions are turned on to the sea cocks; the Engineer Officer that the Kingston valves are open, that all sluice valves and water-tight doors, not ordered to be left open, are closed, and that the steam fire engine is ready for use and hoses connected. The

Fire brigade. stokers of the fire brigade should connect hoses and branch pipes at the fire main deliveries in each compartment.

When the pumps are rigged, and hoses and branch pipes seen clear, the fire brigade should provide shot plugs, bags of oakum for stuffing them, axes, hooks for catching the shot-stopper mats, jiggers for bowsing them in, and tubs of water. All scuttles or ports below the gun deck, or before and abaft the guns, should be closed; if necessary a party being detailed to assist the fire brigade.

Keys of flood cocks. The keys of the magazine flood cocks should be kept by the Captain, or, at his discretion, by the Officer in charge of the lower deck.

Projectiles. The projectile party provide a certain number of projectiles ready for the gun deck, and see the whips, barrows, &c., ready for use.

Electric gear. The directors should be seen in position and electric firing gear prepared.

The following directions are to be observed on this point:—

The circuit should at all times be ready for use, the wires connected and the battery box locked.*

Miscellaneous. Cases of gun tubes are to be placed in the boxes fitted for them, and a plentiful supply issued to the guns.

An ample supply of drinking water should be provided on all decks. Men stationed to strike down wounded provide whips, chairs, stretchers, &c.

Arrangements should be made for fitting time fuzes, should they be required. This, however, so long as the present wood time fuzes are supplied, will seldom be the case.

Shell would not be filled in action.

The Officers of quarters report when their guns are loaded and run out.

"Advance." The order should then be given to provide arms and stores by bugle call ("Advance"). In turret ships some other bugle call must be selected for this purpose.

The guns' crews then fall out by order of the Officer of the quarters, pass down and stow away tables and stools (if not already done), and securing chains or screws, and provide their arms.

Providing arms. Every man having a rifle should provide it, unless he is armed with a pistol at quarters.

Waist belts, pouches, and pistols should be worn.

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* After testing, the wire should be connected, the box locked, and a broadside of drill tubes fired on each side. This ensures no alteration being made after the practical test.

**Providing arms.** The upper deck parties should place their arms in ready racks at their quarters; the remainder put their rifles in ready racks fitted for the purpose in some convenient place, and take their side arms to their quarters, placing them in racks near their guns.

The best place to keep at quarters the rifles of men stationed below, would usually be at the appointed mustering station of their division of boarders.

Men should be specially stationed to provide and place these ready racks on going to quarters.

In turret ships special arrangements must be made.

**Other duties.** On returning to their quarters, any spare gear which may be required should be provided, battery doors closed, hoses in the battery screwed on to fire mains (should stokers not be stationed for this duty), and if necessary projectiles got out of the racks on the gun deck, and placed ready for use.

Tubs of water for damping sponges should be brought to the guns.

When finished, the guns' crews close up, and by order of the *Officer* of quarters the flaps are taken up (or rear screws taken off) and the guns' crews numbered and closed up.

The rear screws should be kept on the gun deck ready for securing the slides, should the guns' crews be called away.

**Officers report.** The Officers of quarters make a careful inspection of their quarters and report.

## Supply of Projectiles.

The question of supply of projectiles is an important one with the present fittings of most ships, *i.e.*, with one large shell room to supply a number of guns.

**Difficulties.** With heavy guns, on the one hand, it is extremely difficult to keep up a constant supply from the shell room; and on the other hand, collecting a number of filled shell together on the gun deck, or deck below it, which is usually above the water-line, should for obvious reasons be avoided.

Present-use lockers on the deck below the gun deck are generally liable to this latter objection.

With unarmoured ships carrying heavy guns, where only one filled common shell may be kept on the gun deck, and where this is the projectile which will usually be employed, it will require careful organisation and a large party to keep up an efficient supply.

Another point, which must be considered in connexion with

the supply of shell, is the probability of the watertight doors being closed. In this case the supply from the shell room will at once be cut off from the majority of heavy guns, as it is in most ships impracticable to carry a supply of projectiles along the gun deck past the rear of the guns.

Projectile parties.

The projectile parties should get a certain number of projectiles ready for supply to the gun deck.

The manner in which this is done will depend entirely upon the special fittings of the ship, size and number of guns, and on whether she is or is not armour plated, as upon this latter fact depends the stowage of projectiles on her decks.

Places of supply.

As far as possible by the use of coal bunker scuttles, &c., each gun should have its own place of supply to which the projectiles would be supplied from the racks on the flat deck, or if watertight doors are open, and there is time, from the shell room.

A small number of projectiles should be kept at each place of supply ready for use, and it will be the duty of the projectile parties to keep up this supply, using the projectiles in the nearest racks on an emergency; but during any cessation of the firing repairing to the shell room, and completing not only the ready supply, but also the racks, in case the watertight doors should be closed.

Guns' crews.

The guns' crews will have the duty of whipping up the projectiles from these places of supply to the guns, but should not leave the gun deck.

## Supply of Powder.

Broadside

In ships of the old broadside class, and in those which carry light guns, the supply of powder is not a matter of difficulty.

It usually would be passed by the magazine men direct from the magazine scuttle to the gun deck, where it would be received by the powdermen, and conveyed along the deck in rear of the guns.

New class.

Where however the guns are cut off from the remainder of the deck by bulkheads with closed doors, the deck below being divided into compartments by means of watertight doors, which frequently would be closed in action, the supply of powder becomes a matter of great difficulty and requires careful attention.

Heavy charges.

The great weight of charges also complicates the question of supply from the magazine, and entails the employment of much stronger men than was the custom in the older ships.

The supply of powder to heavy guns should be from the magazine scuttle, along the deck below the gun deck, and

where practicable should come up near the gun, each gun having its own place of supply.

Should the doors below be closed in a central battery ship, the battery doors would have to be partially opened, or else the supply would have to come over the upper deck.

Both these courses are objectionable, but the former would probably be the least so.

As far as possible the arrangements should be made so that each quarters are supplied from their own magazine.

Officers responsible.

The Officer in charge of the deck below and the Officers under him are responsible that no accumulation of powder is allowed between the magazine scuttles and the gun deck.

The maximum amount on the decks (besides the charge in the gun) should be, for guns receiving supply along the gun deck, two charges; and for those receiving supply from below, one charge on the gun deck, and one on the deck below. The Officers of quarters are responsible for this as far as the gun deck is concerned.

Risk of explosions.

If a heavy charge be accidentally ignited there is risk that others within a certain distance may be exploded, and to avoid this danger as much as possible two charges should never be allowed to be near each other.

Experiments lately carried out by the Committee on Explosives showed that a cartridge in a Clarkson's case, properly closed, was not ignited by the explosion of an 80 lb. charge of P or $P^2$ powder at a distance of 4 feet in a somewhat restricted space.

From these experiments it would seem that the danger of fire being communicated to the magazine in this manner is somewhat less than might be expected, but every precaution should be taken to make the access to the magazine as indirect as would be consistent with facility of supply, and the magazine doors and scuttles should be closed when the supply of powder, as given above, is completed.

Unloading.

At the termination of the action the guns are to be unloaded and the cartridges very carefully examined.

If the powder is found to be perfectly dry, it is to be emptied into another cartridge bag and returned to the magazine as spare powder; otherwise it is to be thrown overboard.

Should, however, a missfire have occurred, the cartridge is always to be thrown overboard.

## Fire in Action.

Officers' stations.

The officers in charge below should have special stations where they would be found if not employed elsewhere. In case of fire instant notice should be given to them.

All fires below the gun deck will be extinguished by the

Necessity for instant action.

fire brigade. With the present system of fire mains in each compartment this should hardly ever require the assistance of guns' crews, but it should be impressed on the men attending the hoses that in case of fire they should act instantly and independently, as a small quantity of water applied on the spot is better than a much larger amount after the fire has made head.

The watertight doors of the compartment should be closed, and hoses should not be brought from other compartments or decks without special orders.

Near magazine.

If a fire occur in the magazine compartment, or so near a shell room as to be dangerous, the magazine or shell room must be closed, the men stationed there, if required, assisting to extinguish the fire. It is advisable that an additional supply of water should be available for the magazine compartments.

If the supply of powder or projectiles is stopped, instant notice should be sent to the Officers of the quarters which are supplied from this magazine or shell room, and also to the Captain. The powdermen and shell party should be exercised in this contingency.

No special stations are required as men are already at the hoses.

On gun deck.

In the case of a fire on the gun deck, the hoses from the nearest fire mains must at once be brought. If stokers are not stationed to attend these hoses, men belonging to guns' crews should be told off.

Any powder or filled shell near the fire must be removed; should the fire be near enough to any gun to interfere with its working, or be so serious as to require more power for its extinction, the Officer of quarters must order one or more guns' crews to assist in putting it out.

The guns' crews, however, should not be sent off the gun deck unless absolutely necessary.

In central battery ships a fire on the gun deck before or abaft the battery should be attended by the fire brigade as if it were below.

On upper deck.

A fire on the upper deck or aloft would be extinguished by fire main hoses and by the riggers. If serious, other steps would be taken.

## Boarders.

Divisions.

In large ships there should, as a rule, be three divisions of boarders.

The starboard watch of guns' crews and of upper deck parties form the first division, and the port watch the second.

The third, or reserve division, would consist of all remaining available men.

Top riflemen, and machine guns' crews, however, will not leave their stations without orders, as they will probably be more useful there.

Each division will have a place of muster, to which the men will repair when called, after securing their guns, bringing their arms from their quarters, and falling in by guns' crews. **Muster place.**

The muster place would, as a rule, be on the engaged side, and for the 1st and 2nd divisions the men, being taken from the disengaged guns, would fall in on the opposite side to which they belong.

The reserve division should also have a muster place, the position of which would depend on the particular circumstances of each ship.

The upper-deck parties and all marines fall in with rifles, the remainder with cutlasses and pistols. **Arms.**

If it is required to repel boarders, all riflemen will take their rifles from the racks, and the remainder will arm themselves with pikes.

The divisions of boarders should be as much as possible under command of the Officers of the quarters to which they belong. **Details.**

In boarding, the riflemen should be used to cover with their rifles the attack of the cutlass men. They should be taught to occupy every available place, keeping together by guns' crews, and as much as possible under cover, and arrangements should be made for providing extra firing places as mentioned in "Action."

Boarders, when fallen in, should be as close as possible to the ship's side; when they are moved, it should be at the double, and as much under cover as possible, and they should never be allowed to show above the netting till actually in collision with the enemy, as with the recent great development of machine gun and rifle fire, any body of men in full view would suffer severely. **Cover.**

Although certain fixed stations are named, yet it must be clearly understood that these are only places of assembly, to which the Captain's orders would be transmitted, and the great importance of not bringing men under fire till actually necessary should always be remembered.

It is considered that in most ships the gangway on the engaged side would give as much shelter from fire as can be found, yet if from any peculiar circumstances this should not be the case the men should at once be moved.

Drill. It should be remembered that from the very nature of the exercise it is impossible to drill at boarding in the same way as at the great guns. All therefore that can be done as a gunnery exercise consists in organising the boarders and placing them in position; the real exercise to cultivate the necessary dash and agility will be found in spar and sail drill.

Turret ships. In many ships special circumstances may necessitate different arrangements. This is particularly the case in turret ships, when the rifles would not be on the upper deck and the men would naturally fall in on the disengaged side until required.

Sail trimmers. Divisions of boarders may be used as sail trimmers.

## Arrangements for Wounded.

Places for wounded. Places should be set apart for the Surgeon and his Assistants; these places should be as safe from the fire of the enemy as possible, and should vary in number according to the size of the ship and number of Medical Officers.

In large ships however there should be at least two places which would naturally be, one before the foremost magazine, and one abaft the after magazine, these being the parts of the ship where they would least interfere with the fighting arrangements.

In ships with weak armour, or none at all, these places should if possible be below the water line.

At each place an arrangement should be made and men stationed to strike down the wounded by means of a slung cot, chair, or cask, from the different decks.

Stretchermen. At each quarters at least two men should be stationed in some central place with a stretcher and a supply of tourniquets; it will be their duty to carry wounded men from the quarters to the hatchway where they are to be struck down.

crews. It will be the duty of rearmen, on the order of No. 1, to place a wounded man clear of the working of the gun, but no man should be allowed to leave his quarters under any circumstance.

It will not as a rule be found practicable to station sufficient carriers to enable the wounded men to be removed clear of the gun without any assistance from the crew.

## Remarks about Action.

General remarks. The considerations which should govern the choice of the particular systems of firing to be used at the commencement,

and during the action will be treated in another portion of the Manual (Chapter XI.), as it is thought better to consider first the questions of trajectory, distance, probability of hitting, and systems of concentrating, all of which have an important bearing on the subject.

The following remarks are intended as hints which may be useful in various circumstances. Some are only matters of opinion, and until experience is gained in actual warfare, must remain so; while others are founded on facts or are theoretically conclusive.

**Charges used.**

The use of battering charges in all cases has been advocated, and their use is now authorised with common shell, the only exception being the 35-ton gun.

The advantages are an increase in battering power and in flatness of trajectory; and the only disadvantage is the increased strain brought on the carriage and slide, the guns and common shell being acknowledged to be fully strong enough.

**Change of charge or projectile.**

The charge and projectile, which it has been decided to employ, should not be changed when once engaged with an enemy, unless some extraordinary circumstance should occur, altering considerably the conditions of the action.

The fact of doing so would materially influence for some time the rate of firing of the guns, and this is especially the case as regards the charge.

It must be remembered that it is not easy to extract the present heavy charges from the powder cases, and that it is extremely difficult to get them back.

This is so much the case that an order has been issued against taking charges out of the powder cases for drill, and thus it is impossible to exercise the magazine men in the varying conditions which would be entailed on them by changing the charges during action.

When it is remembered that these men are of necessity taken almost entirely from the non-combatant portion of the ship's company it will be seen that the argument against a change is very strong.

Changing the charge also involves alteration of the compressors, which may lead to accidents; alteration of sights causing a possibility of error; and complication in the use of director.

There are, however, circumstances where it would become necessary, such as that of finding, after commencing an action with battering charges, that the gun gear was beginning to

fail; or, again, an action may be commenced in ignorance of the nature of the ship opposed, *i.e.*, whether ironclad or not.

**Keeping men in hand.**

Taking men away from their guns for any purpose, except that of actually boarding or repelling boarders, should as far as possible be avoided, as tending to demoralise them.

This is especially the case as regards allowing men to go below the gun deck to put out a fire, or for any other purpose, and with the present improved arrangements as to fire mains, &c., it will seldom be necessary to do so.

**Keeping men out of fire.**

It should be the rule in all ships that the men at disengaged guns should lie down round their guns. They should as a general rule be kept close to the ship's side, as in this position they would be sheltered by the guns from a raking fire, and the order "Lie down," or "Rise up," should be given by the Officers of quarters.

When guns are laid for electric firing by director the guns' crews should lie down without orders as soon as the guns are laid.

**"Lie down."**

If the captain sees that there is a probability of receiving a destructive fire it would be well to cause everyone exposed to lie down at his station by the use of the bugle call "Lie down," followed when the danger is over, or on an emergency, by "Rise up."

In such flush decked ships as have full guns' crews for both sides, at close ranges, it would probably be better to cause the riflemen from the disengaged side to cross the deck and to use their small arms against the enemy, and in some exceptional cases, where it is probable that one battery only would be engaged, special arrangements might be made in maindeck ships for the riflemen of the disengaged side to be stationed on the upper deck with their rifles.

**Smoke.**

Much uncertainty at present rests on the question of smoke; on the one hand many officers consider it most important, and that it would influence not only the description of firing to be used, but also the tactics adopted; and on the other hand there is an equally strong body of opinion to the effect that with the present ships, travelling at high speeds and carrying comparatively few guns, smoke would, as a rule, not interfere much with the conduct of an action.

So far as regards smoke outside the ship, it is probable that with few exceptions (such, for example, as the ship moving for any length of time in the same direction and at the same speed as the wind, or keeping directly to leeward of an enemy close to) the latter opinion would be the more probable in

single ship actions; while in general actions the former would generally be found to be the case. Smoke.

The state of the atmosphere exercises a good deal of influence on the hanging of smoke.

The best method of firing the guns, so as to avoid this difficulty, will be treated in Chapter XI.

As regards the smoke on gun decks and inside turrets, with the system adopted of closing the ports immediately, there would not be many vents for its escape, and it might be necessary in some cases, as for instance a shell bursting, or an explosion, to keep the ports open for a time, but this would probably be rarely necessary when the smoke of the guns only was in question. The proper ventilation of the battery requires however consideration, especially as the use of breech-loaders may entail a larger quantity of smoke on the gun deck.

Machine gun and rifle fire will probably play an important part in future naval engagements. Speaking generally, there may be said to be four principal objects at which this fire may be directed: Mitraille.

1. Exposed men on the upper deck including helm party;
2. Enemy's machine guns;
3. Battery ports;
4. Conning tower;

and, in the case of heavier machine guns, the sides of batteries thin enough to be penetrated.

The selection of which of these objects should chiefly be fired at depends on the class of the enemy's ship, the position of the machine gun, &c. General instructions on this head should be given to those in charge before the commencement of the action.

If circumstances require that a constant fire should be kept up, an extra party must be told off to fill hoppers, as the guns' crews would not be sufficient.

The supply of rifle ammunition must be kept up both on deck and in tops.

Ships armed with a saluting battery of light guns should fire case when at close ranges.

Every opportunity should be taken during an action to complete the supply of projectiles, so that it may not be necessary to take men away from the guns for this purpose while actually firing. General remarks. Projectiles.

A constant control should be exercised over the bow guns, as it must be remembered that one of these guns fired at a wrong time may obscure the view of the enemy at a critical moment and lead to disaster. Bow guns.

The collision mats, shot hole stoppers, and the sail which it is recommended to keep on deck for stopping leaks should be kept ready (see Chapter XXI.).

Water aloft.

In ships going into action with their sails bent there will be a danger of fire, and the top riflemen should have with them a certain number of fire buckets, filled with water.

Whitehead torpedo.

As regards the Whitehead torpedo, its presence in an unprotected part of the ship must be considered as a danger, and every precaution should be taken to minimize the result of an explosion.

Where this torpedo is carried in the midst of the guns this cannot be carried out.

## Duties of Officers of Quarters.

Keeping men in hand.

They should pay great attention to keeping their men in hand, and should, as much as possible, prevent any undue excitement and hurry, remembering that rapidity is of no use if the shot is lost, but the loss of time due to over-careful laying must equally be avoided.

Guns correctly laid.

They must pay the greatest attention to communicating to the guns the changes of distance, and to seeing that they are properly laid, especially in broadside firing.

The wood scales, however, as at present fitted prevent their ascertaining without delay if this is the case as regards elevation.

Independent firing.

In the case of independent firing they must watch to see that the guns are firing in the right direction.

Directing gun firing.

In directing gun firing the Officer of the quarters should personally superintend the directing gun, from some point close to; at exercise he should practise firing broadsides, so as to accustom himself to estimating the time allowed by No. 1 between the signal to fire and the delivery of the broadside.

Stations. Spare stores.

Officers of quarters should be thoroughly acquainted with the various stations of the men under their command, for putting out fires, closing watertight doors, &c., and should know exactly where any spare gear which may be required in action is to be found.

Supplies.

The supply of powder, projectiles, and tubes to their quarters is a most important point to which they should direct their attention.

## Defence against Torpedo Boats.

This is of two kinds:—

Two kinds.

1. Passive, consisting of obstructions; and,
2. Active, of guard boats and fire from guns and small-arms.

Passive.

The first can only be used for ships at anchor or perhaps

steaming at moderate speeds (see Torpedo Manual), and will always be combined with an active defence.

Guard boats and small craft would as a rule be employed in this case, and could also be used for the protection of a fleet steaming at moderate speeds. **Guard boats.**

Fire from guns and rifles can be used in combination with either obstructions, guard boats, or both, or by itself; and in every ship stations should be arranged so as to give the most efficient defence under various conditions, remembering that small craft can not be employed on water which is swept by artillery fire. **Fire.**

These arrangements would consist in keeping a certain number of men as a night watch, in the most favourable positions, who would, if time allows, be supplemented at the order "Man and arm ship" by the whole ship's company. **Night stations.** **Man and arm ship.**

The stationing of the first body should be so arranged that this reinforcement can be carried out quickly and without confusion.

The night watch would probably consist of at least one part of a watch, and a certain number of idlers.

All the seamen of this party should be armed with rifles, and for this purpose special arrangements should be made, by temporarily issuing rifles belonging to men stationed at the great guns, so that the general arrangements for action may be least interfered with when all hands are called. Ammunition should be issued and depôts formed at various places on the upper deck. **Rifles.**

The guns to be manned should be the machine and small guns, and others according to circumstances. The machine guns should be kept with the hoppers filled and in position, so that they may be worked efficiently with small crews. The small guns, and any others it is intended to use, should be loaded with case; as a rule it will be advisable to train them beforehand so as to cover as much of the ship as possible. It would probably be found that their fire would be more effective at night on this plan than if worked even with full crews. Bow and stern guns, however, must be worked. **Guns.**

At the order "Man and arm ship" the night watch should remain at their stations. The remainder of the ship's company armed with rifles, except Nos. 1 and 2 at great guns, will repair to a fixed station on the upper deck, and the rest will go to their stations at general quarters. **Man and arm ship.**

The arrangements on the upper deck should be based either on the watch or quarter bill, and the Officers specially stationed.

These exercises should be frequently carried out. **Exercise.**

## General Quarters

Object.

General Exercise at Quarters is for the purpose of perfecting all the arrangements which would be required in action under various conditions, and not for teaching the details of drill. Guns' crews should not, as a rule, be broken up for the purpose of filling up vacancies at other guns, but, when necessary, the guns should be worked with diminished crews.

Small-arm and machine gun ammunition should be provided; but not issued, except when the ship is at target practice, when a certain proportion of ammunition should be fired.

Loading guns.

The guns should be loaded with dummy charges and a projectile rammed home. After this the powdermen and magazine men work with empty cartridge cases.

Exercises.

At every General Exercise at Quarters a portion of the time should be employed in carrying out all the arrangements exactly as they would be conducted in action. The orders to the quarters and magazines, &c., should be communicated from the positions selected for the Commanding Officer to occupy in action, and the communication and battery doors should be closed, to accustom Officers and men to use only those ladders and hatchways which would be available in action, and to ensure the free working of the doors. The supply of powder and of the various descriptions of projectiles should be frequently carried out under these circumstances.

Casualties to Officers.

The liability of casualties occurring to Officers as well as to the men should be borne in mind, and the filling up of such casualties practised.

The distance of the object on which the fire is to be directed should be constantly communicated by the Officer detailed for observing it.

Working round target.

The best way of simulating at exercise the circumstances of an action would be to manœuvre under steam round a target or another vessel, and so exercise the different systems of firing. A useful method of carrying this out will be found in the Remarks on Target practice, p. 452. Much practice can be acquired in this way in the management of the directors, and in steering so as to pass an object at a previously arranged distance, as well as in accustoming the men to lay their guns quickly for a moving object at a varying distance. Firing blank cartridge when two ships are working as targets for each other would show the effect of smoke on an action, and afford opportunities for studying under these circumstances the most effective system of firing.

At the conclusion of General Exercise at Quarters the bugle call for "Return Arms" should be sounded, when the ammunition should be returned, magazines and shell rooms closed, the pumps unrigged, and stores returned; the Officers of quarters then order "Fall out," "Return Arms;" on coming back to their quarters, the men close up, and wait orders to clean or secure the guns. **Conclusion.**

## NIGHT QUARTERS.

On the call for action all hammocks should be partially lashed up, and those which interfere with the fighting arrangements placed on the upper deck, abreast their proper nettings, clear of the guns, ready to be stowed and covered by the riggers and top riflemen; those left below should be triced up close to the beams. **Hammocks.** Ladders should be set apart for men going to, and returning from, the upper deck. **Ladders.**

The fighting lanterns should be immediately lighted, men being told off for this purpose, and all unnecessary lights which show outside the ship, such as cabin lights, &c. should be extinguished. **Lights.**

Men told off for opening and lighting the magazines, buglers, voice-tubemen, &c. should repair to their stations without lashing up their hammocks.

These stations should be first practised by daylight, and should not be carried out in the dark until a fair amount of efficiency is attained. **Practised by day.**

Night Quarters for Exercise is intended as a surprise; it should take place without any previous warning, and not before 10 p.m. **Method of carrying out.**

Whenever a ship goes to night quarters the first duty is to get the guns cleared away and ready for action. With a squadron, if a blue light is ordered to be burnt or other signal made when the guns are clear, this should be done when the Officers of the quarters have all reported. If blank cartridge is to be fired, which should be done occasionally to test the efficiency of lighting, magazine arrangements, &c., either previous warning should be given, or sufficient time allowed after the order is given, to remove fittings, glass, or other Government stores likely to be damaged. **Firing.**

# GUNNERY.

# CHAPTER II.

## GUNS.

### Materials.

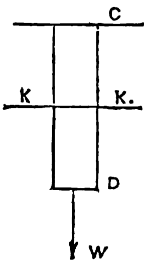
#### *Explanations of Terms.*

Stress. Stress is the general term used to comprehend the various forces, whether tensile, compressive, or shearing, which may act between bodies and parts of bodies.

Strain. Strain is used to denote the alterations in the form or dimensions of a solid body produced by the application of a force.

Elasticity. Elasticity is the property possessed by a metal of resisting permanent deformation when subjected to a stress, and is measured by a coefficient expressing the ratio of stress to strain. Thus, if a bar CD, fixed at C, is stretched under the action of a weight W, the tendency of the load is to tear the bar asunder across any section KK. This tendency is called the stress on the bar, and if A = area of cross section, the intensity of the stress $(p) = \frac{W.}{A}$ Also, if $x$ = the extension due to the load (W), and $l$ = length of the bar, then $\frac{x}{l}$ = the strain $(a)$, and the coefficient

Fig. 1.




Modulus. or modulus of elasticity $= \frac{\text{stress}}{\text{strain}} = \frac{p}{a}$.

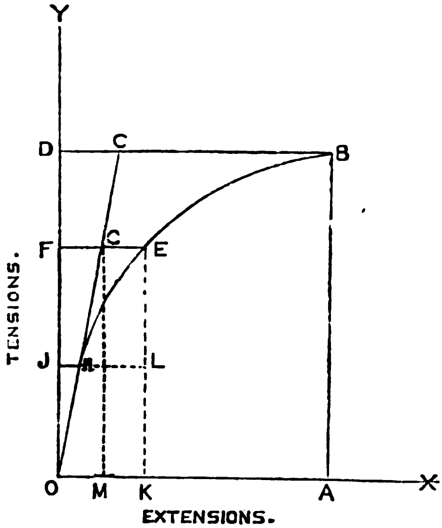
Elastic limits. The elastic limit is the smallest stress, which can cause permanent alteration of form. For tension it is represented in the figure below by the ordinate OJ.

Tenacity. The ultimate strength is the stress required to produce fracture. For tension it is sometimes called *tenacity* or *limit of fracture*, and is represented in the figure by the ordinate OD.

The following explanation is taken mainly from the official text book on the construction of ordnance.

In the figure below, the ordinates represent the tensions, and the abscissæ the corresponding extensions of a bar of metal.

Fig. 2.




If the bar be subject to a constantly increasing tension the extension is at first in a constant ratio to the tension, increasing after a certain point in a varying ratio. This point is represented in the diagram by H where the extension is HJ, and the tension OJ.* Effects of increasing stress on a bar.

After this point is reached the bar becomes permanently deformed, the extensions increasing in a higher ratio for every increment of tension, and the line joining the ordinates becoming a curved line, as shown by HB in the figure. As the tension is increased a point is reached when the bar will fracture. Suppose the total extension of the bar at that point to be represented by BD, and the breaking tension by the ordinate OD, which is the measure of the tenacity or limit of fracture; there are, as will be seen by the figure, three extensions of the bar, the total, elastic, and permanent, the former being in all cases the sum of the two latter; while, until the elastic limit is reached, the total is synonymous with the elastic extension. Measure of the limits of fracture. Total, elastic, and permanent extension.

* This, however, according to Mallet, p. 57, is not invariable. With wrought iron, for instance, should the tension exceed one-fourth the tenacity, the extension will slowly increase with time.

The abscissæ of the curve OB (a straight line as far as H) represent the total extensions, and the abscissæ of the straight line OC the elastic extensions of the bar, while the *work* * required to produce rupture is measured by the area AOB.

Similarly the work necessary to produce a total extension EF is measured by the area KOE.

If the tension represented by OF be removed after the bar has been extended by EF, and then re-imposed, the greatest extension of the bar caused by this re-imposition of the tension will not exceed FG;† because it has been permanently extended by the amount GE, and if the tension be once more removed the bar will revert to its former length, *i.e.*, its original length + the permanent extension EG.

Work done upon a bar of metal.

Here, of the total work done on the bar, represented by the area OEK, a portion equal to the difference between the areas OEK and OGM has been absorbed by it and applied to the re-arrangement of its molecules, permanently extending the bar by the amount EG, and is the measure of the loss sustained in the work which can be done on the bar. Its ultimate strength may, however, be increased, and in the case under consideration the elastic limit is so, while the work required to be done to produce rupture is diminished. In fact a material strained beyond its elastic limit will exhibit the same characteristics as an originally harder metal.

To recapitulate, then, it must be remembered that increase in the tenacity (or breaking tension) and limit of elasticity do not necessarily imply greater working strength in a given bar of metal. In fact to fracture steel of great tenacity less work done may be necessary than is required to fracture a similar bar of soft wrought iron. It is of the utmost importance to distinguish between the work done and the stress applied, because the power of a material to resist suddenly applied forces depends mainly upon the amount of work which can be done upon it.

Importance of distinguishing between stress and work done.

Measure of elasticity.

Again, the elasticity of the iron may equal that of the steel, but the limit of elasticity may be very different in the two cases. The elasticity is measured by the cotangent of the angle COD in the figure, while the elastic limit is represented by the tension measured by the line OJ.

Metals

The metals ‡ employed in constructing ordnance are bronze, cast or wrought iron, and steel.

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* *See* p. 96.

† This extension increases very slightly in proportion of the duration of the tension.

‡ Treatise on the Construction of Ordnance, 1879, p. 4.

## *Bronze.*

Bronze, an alloy of copper and tin, is an expensive material, too soft for the bore of a rifled gun, and further liable to flaws, due to the want of proper mixture of its constituents. It is tough,* but wanting in elasticity and tenacity. **Bronze.**

Much advance has recently been made in the treatment of this alloy, and more particularly in a description known as bronze steel, which contains 8 per cent. of tin, can be forged cold, possesses many of the properties of steel, and has been largely used in Austria for the construction of light guns. **Bronze steel.**

Phosphor bronze contains small quantities of phosphorous, and is a metal of a more uniform character and stronger than ordinary bronze. **Phosphor bronze.**

## *Iron.*

Iron is one of the elementary metals, to which a great variety of properties can be given by mixing comparatively small quantities of other elements, and by proper treatment in the process of manufacture. This has led to dividing iron into groups termed respectively cast iron, wrought iron or piled metal, steel or ingot metal. Iron is usually obtained from its ores by melting them in large blast furnaces with coke or coal, various fluxes being added, according to the nature of the ore, to carry off the earthy matters; the metal so obtained is run into sand moulds in the shape of the well known rough looking bars technically termed "pigs" or "pig iron." **Varieties.** **How iron is usually obtained from its ores.** **Pig iron.**

## *Cast Iron.*

The metal in this state, as run from the blast furnace, is termed cast iron, and contains many foreign elements, principally carbon and silicon, the former being mostly derived from the fuel with which the ore was smelted. Besides these impurities, small quantities of sulphur, phosphorous, and manganese are commonly found in cast iron when first run out. **Cast iron.**

By refining, &c. a portion of the carbon and other impurities may be removed, but so long as the proportion of carbon is not less than 2 °/₀ the metal will possess the characteristic properties of cast iron mentioned below. The presence of silicon, sulphur, and phosphorus modify the strength, brittle- **Refining.**

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* Toughness is a term generally understood; it refers to the capacity of a body for bearing alterations of form, and the *ultimate toughness* bears the same relation to strain that the ultimate strength does to stress.

ness, &c. of cast iron very much, that of sulphur in particular increasing its tenacity, which is always, however, comparatively low.

Per-centage of carbon.

We may say that cast iron contains from 2 °/。 to 5 °/。 by weight of carbon, which exists in two states, either chemically combined with the iron or mechanically mixed with it.

Various qualities.

In the trade, cast iron is distinguished by numbers, from one to eight, the lowest numbers being given to those descriptions in which the surface when broken presents a "grey" or "mottled" appearance, and in which the larger part of the carbon is in the state of graphite, that is, uncombined with the iron. The higher numbers represent "white" or "bright" iron, and in these the carbon is almost entirely in the combined state.

The intimacy with which the carbon is combined with the iron depends not only on the description of the metal, but also on its treatment, rapid cooling tending to produce white iron in varieties which, if cooled slowly, would be grey.

Properties.

Cast iron is cheap and easily worked, but its tenacity is low as compared with other iron, being on an average about half that of wrought iron. It can be fused and cast without difficulty, and is comparatively hard. It is not malleable, and is therefore incapable of welding. It is brittle and uncertain in character, on account of which, and of its comparatively low tenacity, this metal can only be used as the sole material for guns which are intended to withstand a low internal pressure.

### *Wrought Iron and Steel.*

It is practically impossible to draw an exact line between iron and steel.

Wrought iron.

Wrought iron approaches to theoretically pure iron, and is sometimes defined as iron containing from 0·1 °/。 to 0·3 °/。 of carbon.

Steel.

Similarly, steel is sometimes defined to be iron containing a small amount of carbon, an amount less than that present in cast iron, but greater than the maximum quantity to be found in characteristic wrought iron, *i.e.*, iron containing between 0·3 per cent. and 2·0 per cent. of carbon is termed "steel."

This proportion of carbon is, however, only approximate, and Dr. Percy gives from 0·5 to 0·65 per cent. of carbon as the limit at which, when free from other foreign matter, iron may be considered as passing into steel, so that when hardened by quenching in water it will strike fire readily with flint.

Definition of steel according to its physical condition and mode of manufacture.

A simpler definition, and one more in harmony with the current modes of manufacture, is to define steel as a *melted malleable alloy of iron,* produced in *any way whatever, and containing a smaller proportion of carbon or other hardening element than is contained in cast iron.*

Structural difference between steel and wrought iron.

It is held, according to this nomenclature, that steel and wrought iron cannot be always distinguished by chemical analysis, (for the same proportions of carbon, manganese, silicon, &c. may exist in any malleable alloy of iron), and that the fundamental and essential difference between steel, and compounds of iron merely worked or wrought, is structural.

All malleable products of iron industry, that is to say, all varieties of iron, except cast iron, may be divided into piled metal (wrought iron), and ingot metal (steel); the former embracing all malleable iron or alloys of iron produced without fusion of the metal while in a malleable state, and the latter applying to all irons, however produced, which are cast into a malleable ingot.

Differences in mode of treatment, &c.

"These two classes differ more widely in mode of manufacture, appearance, and in many important properties than the varieties of each class among themselves, and form two parallel and continuous series, the corresponding members of which are chemically identical, differing only in mode of production, and in mechanical structure, and rising in each series from the purest and softest iron to the hardest and most highly carburetted varieties."*

Manufacture of wrought iron.

Wrought iron is obtained from cast iron by burning out the carbon, and then subjecting it to mechanical treatment for the purpose of removing other impurities, and of producing the fibrous structure, which is an essential characteristic of wrought iron.

Manufacture of steel.

Steel may be produced in a variety of ways, by more or less decarburetting cast iron under such conditions as to obtain a melted product.

By dissolving wrought iron or steel scrap or spongy reduced iron in melted cast iron.

By the direct melting of puddled or other variety of iron containing the requisite amount of carbon.

By melting a mixture of soft wrought iron or iron sponge with carbon or with cast iron; of malleable iron, which is too hard for the variety of steel required, with oxidising agents; or by directly melting together a mixture of iron ore and carbon as a single operation.

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* Journal of the Iron and Steel Institute, 1873, p. 499.

Cemented steel. A variety of steel may also be produced by a process known as "cementation," which consists in heating wrought iron in contact with carbon until the proper amount has been absorbed. This cemented steel, not having been reduced to the melted state, must not, however, be considered as a true steel.

Crucible steel. The processes by which steelmaking is practically carried out are by melting in pots or crucibles, giving "pot" or "crucible" steel; on the open hearth or bed of a reverberatory furnace, giving Siemens or Siemens-Martin steel, or by blowing air through molten cast iron, producing Bessemer steel. In whatever way made the material is essentially the same, depending on its chemical composition and physical structure for its properties. It differs much from wrought iron, even when chemically the same metal, because a mass of wrought iron is made up from a number of bars or blooms, heated and welded together, each of these again being composed of separate granules with impurities interposed, such as slag, &c., entangled so that the mass is unavoidably full of flaws and imperfect welds. Steel, on the other hand, has been brought into a state of perfect fusion, and cast while liquid into a malleable ingot, which is homogeneous throughout, and free from flaws or intermixed impurities.

Siemens and Bessemer steel.

Flaws likely to occur in wrought iron.

Steel free from such flaws.

It can now be fully understood what steel means in accordance with either of the definitions given of the term, whether depending merely upon its chemical constitution as to the amount of carbon present, or upon the physical treatment of the metal, which must be melted and cast into a malleable mass.

Varying properties of steel. In either case the properties of the metal vary very much, the soft or low steels approximating to ordinary wrought iron, while the hard or high natures of steel approach cast iron in their properties.

Advantage of steel over wrought iron. Over wrought iron steel has always the advantage of being homogeneous and pure, but it is unfortunately uncertain in quality, a surprising fact when its manufacture is considered; still it is so, and ingots of this metal of the same chemical constitution, produced in the same way and from identical materials, often differ much from one another in the properties of elasticity and tenacity.

Uncertainty in the quality of steel.

Casting under pressure. Many plans are being tried for the purpose of insuring greater certainty in the quality of steel, such as casting it under pressure, to get rid of the bubbles or blow holes.

Steel will not, like wrought iron, stand a high welding heat, especially if it be of a "hard" or "high" nature. If hammered at too great a heat the ingot will fall to pieces. This is a very important point in which steel is inferior to wrought iron.

After being cast, steel is hammered or rolled, and it acquires a fibrous structure during this process, as may be easily shown if a bar of this metal be acted on by a strong acid. Hammering and rolling makes steel fibrous.

When first cast, steel, excepting the higher varieties, is comparatively soft and inelastic, and can thus be treated in a similar manner to wrought iron; but with the exception of the very low or soft varieties,* it may be subsequently hardened by what is called "tempering," when the metal is heated and plunged into mercury, water, oil, or some other liquid, in order to cool it more or less quickly. The effect of such tempering depends very much upon the nature of the medium in which it is cooled, and upon the amount of carbon present in the steel, as well as upon the degree of heat it is previously raised to; it increases the tenacity and elastic limit, but diminishes the extensibility of the metal. Tempering steel.

The effect of tempering various qualities of steel is shown in the following table, quoted by Mr. J. A. Longridge.†

| Per-centage of carbon. | Standard in Natural state. | Limit of Elasticity. | | Rupture. | | Stretching at rupture. | |
|---|---|---|---|---|---|---|---|
| | | Oil. | Water. | Oil. | Water. | Oil. | Water. |
| Bars ·55 in. square. | | | | | | | |
| ·150 | 100 | 149 | 140 | 131 | 137 | 84 | 56 |
| ·490 | 100 | 170 | 173 | 144 | 161 | 50 | 10 |
| ·709 | 100 | 215 | Broke in tempering. | 158 | Broke in tempering. | 27 | Broke in tempering. |
| 1·050 | 100 | 265 | " | 143 | " | Broke. | " |
| Bars ·787 in. square. | | | | | | | |
| ·150 | 100 | 172 | 182 | 129 | 138 | 73 | 68 |
| ·490 | 100 | 190 | 214 | 148 | 168 | 51 | 34 |
| ·709 | 100 | 220 | Broke in tempering. | 142 | Broke in tempering. | 15 | Broke in tempering. |
| ·875 | 100 | 237 | " | 143 | " | 10 | " |
| 1·050 | 100 | 235 | " | 152 | " | 22 | " |

* Thus, "Some varieties of soft steel used for boiler-plates, having less "carbon than many wrought irons, may be heated to redness, quenched in water, "and subsequently bent double without cracking, or may be twisted into any "form, like as much lead." *Vide* Proceedings Institute C.E., Vol. XLII., Part IV.

† Journal R. U. S. Institution, Vol. XXIII., p. 928.

All the above results are strictly comparative. The material in its natural state is taken as 100.

Suitability of wrought iron for guns.

Wrought iron has been much used for the manufacture of guns, for which its toughness and welding properties, as well as the power of arranging the fibre in any required direction, render it peculiarly suitable. On the other hand, its softness, liability to flaws and defective welds, and comparatively low limit of elasticity, are the corresponding disadvantages.

Suitability of steel for guns.

The want of accurate knowledge of steel has hitherto prevented its general introduction as the sole material for any gun. It has, however, been much used for the inner barrel, as it gives a hard clean surface to withstand the action of the gas, while its limit of elasticity is high, so that a comparatively heavy stress does not stretch it permanently and deform the bore.* Opinions differ as to its suitability for the exterior portion, some experts holding that its uncertainty, and want of extensibility, render it unsafe; while others contend that its high elastic limit makes it less liable to stretch permanently and leave the inner parts unsupported.

TABLE showing the ELASTIC LIMIT and TENACITY of Average Specimens of the Metals used in the R.G.F.

| Materials. | Tons per Square Inch at | | Elongation per Inch at Breaking. |
|---|---|---|---|
| | Yielding. | Breaking. | |
| Bronze | 6·8 | 14·9 | 0·29″ |
| Cast iron from | about 4 | 9·0 | |
| Cast iron to | | 14·0 | |
| Wrought iron along its fibre | 11·0 | 22·0 | 0·3″ |
| Steel soft | 13·0 | 31·0 | 0·21″ |
| Steel tempered in oil | 31·0 | 47·0 | 0·11″ |

These numbers show of course only a rough average approximation with reference to the particular natures of the metals mentioned which are used in the Royal Gun Factories.

## PRINCIPLES OF CONSTRUCTION.

Work to be done.

The object with which a gun is constructed is to propel a a projectile at a high velocity, and this is done by causing a pressure of greater or less intensity to act upon the shot while within the bore. The pressure required being determined, the question arises, how is the gun to be made strong enough to resist it?

* Some, however, hold that its want of extensibility renders it unsuitable for the inner barrel.

It is proposed to explain briefly the principles on which the answer to this query must be based, first ascertaining the effect of this pressure, and afterwards investigating the capacity of a cylinder for resisting rupture.

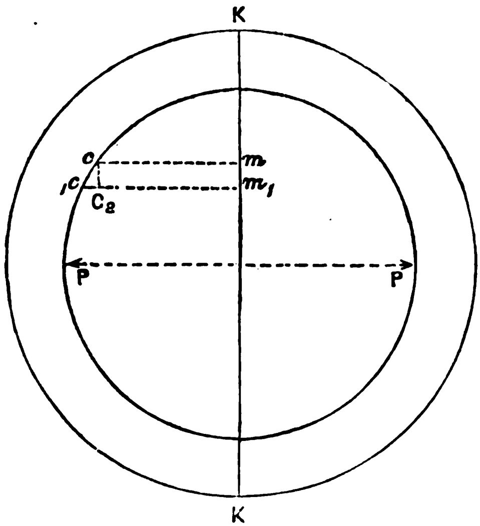
*Internal Pressure in a Cylinder.*

The internal pressure tends :—

1. To split the piece longitudinally.
2. To blow the breech off.

To find the force (P) exerted by an internal pressure to split a cylinder longitudinally. **Circumferential splitting force.**

Fig. 3.




Let the figure represent a section of a cylinder of radius $r$. The internal pressure tends to produce rupture along any diameter KK, because on each half there will be a component P.

Assume $p =$ the pressure on a unit of surface. Then the pressure on any small portion $cc_1 = p \times cc_1$, of which the horizontal component is $p \times cc_2, = p \times mm_1$. Similarly, the horizontal component of the pressure on any small arc is equal to $p \times$ the projection of that arc on the diameter.

Now the sum of these projections makes up the whole diameter.

Therefore each horizontal component $P = p \times 2r$, and the splitting force increases with the size of the cylinder.

Thus, in the case of a cylinder of 9-inch internal diameter subject to an internal pressure of 24 tons per qs. in.

$$P = 24 \times 9 = 216 \text{ tons.}$$

Transverse rending force.

To find the force (L) exerted by an internal pressure to blow the breech off.

Let $p$ = the pressure per unit of surface at bottom of bore, and $r$ = the radius of the bore as before.

Then the force in the direction of the axis of the gun is the pressure per unit of surface multiplied by the number of such units in the area of the bottom of the bore. Therefore,

$$L = p \pi r^2.$$

For the above-mentioned 9-inch cylinder subject to an internal pressure of 24 tons per sq. in.

$$L = 24 \times 3 \cdot 1416 \times \overline{4 \cdot 5}|^2 = 1529 \text{ tons.}$$

*Strength of a Homogeneous Cylinder.*

The capacity of a cylinder to resist rupture by an internal pressure has engaged the attention of many eminent mathematicians, among whom may be mentioned Professor Barlow, who first drew marked attention to the weakness of a homogeneous cylinder. The law enunciated by him may be thus stated:

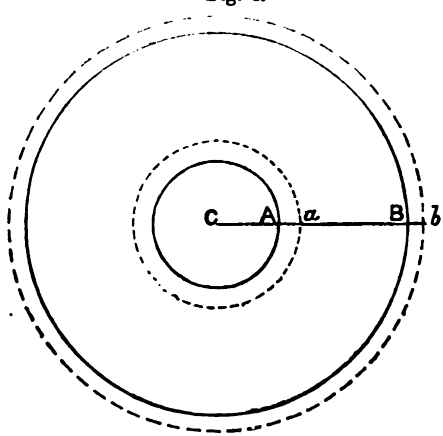
Barlow's law.

In a homogeneous cylinder, if the metal is incompressible, the tension on every concentric layer, caused by an internal pressure, varies inversely as the square of its distance from the centre.

The proof is as follows:—

In Fig. 4 let the solid lines represent the inner and outer surfaces of the bore before, and the dotted lines the same after, extension.

Fig. 4.




Let $CA = r$, $CB = R$.

$Aa = d$, $Bb = D$.

Then, since the metal is, by hypothesis, incompressible, the area between the inner solid line and its dotted line must be equal to the area between the outer solid line and its dotted line.

But the lengths of these areas are as their radii, **Barlow's law.**

$\therefore$ the breadths must be inversely as the radii—

$\therefore d : D :: R : r.$

$\therefore \frac{d}{r} : \frac{D}{R} :: R^2 : r^2.$

Now $d$ and D are respectively the whole increments in $r$ and R;

$\therefore \frac{d}{r}$ and $\frac{D}{R}$ are the increase for each unit of length in $r$ and R;

$\therefore$ the increase per unit of length at inner surface, : increase per unit of length at outer :: $R^2 : r^2$.

But the increase per unit of length is the strain

$\therefore$ strain on interior : strain on exterior :: $R^2 : r^2$

$\therefore$ tension on interior : tension on exterior :: $R^2 : r^2$

hence the tension on any layer varies inversely as the square of its distance from the centre.

Since the metal really is compressible this law is only approximately true, but assuming it to be accurate in the case of a 9″ cylinder as above with sides 12″ thick—

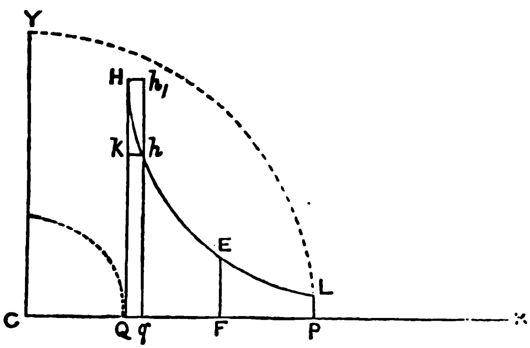
Tension on exterior : tension on interior :: $\overline{4\cdot5}|^2 : \overline{16\cdot5}|^2$
:: 9 : 121;

that is to say, if the stress on the inner layer is 20 tons per sq. in., that on the outer will only be $1\frac{1}{2}$ tons.

Hence is seen the small advantage as regards strength in simply increasing the thickness of the walls of a cylinder.

The following explanation will enable this to be more readily understood:—

Fig. 5.




Let Fig. 5 represent a portion of the section of a hollow cylinder, in which— **Strength of homogeneous cylinder.**

C is a point in the axis.

CQ, the internal radius $= r$.

CP, the external radius $=$ R.

Strength of homogeneous cylinder.

Take CX and CY for axes of co-ordinates,
and make HQ = tension at Q = T
FE = tension at a distance $x$ from the axis = $t$.

Then, assuming Barlow's law to hold—

$$t : T = r^2 : x^2.$$

$$t = \frac{Tr^2}{x^2} \qquad (1).$$

This equation is represented by the curve HL.

If HQ represents the tension to which the inner layer may be safely strained, the whole useful strength of the cylinder is represented by the area HQPL, because the useful strength of any layer is equal to the stress to which it is subjected multiplied by the thickness of the layer, and may therefore be represented by the area of a rectangle; also the area HQPL may be conceived to be made up of an infinite number of very narrow rectangles.

In the case of the layer of which the thickness is Q$q$, if the tension at every point is equal to HQ, the useful strength will be represented by HQ$qh_1$; but if the tension at every point is equal to $hq$, then the useful strength will only be $k$Q$qh$. The actual useful strength will lie between these two extremes, and if Q$q$ be taken so small that H$h$ may be considered a straight line, will evidently be represented by the area HQ$qh$.

Similarly for each of the layers of which the cylinder may be supposed to consist.

The area of the curve can be found either by Simpson's first rule, or from the following formula derived from Eq. (1.) by means of the integral calculus.

$$\text{Whole useful strength (S)} = \text{area HQPL}$$
$$= Tr\,\frac{R - r}{R}, \qquad (2)$$

in which T = the tension to which the interior may be safely strained.

In the case of a 9″ cylinder as above, of which the material can withstand a stress of 20 tons per sq. in.

$$T = 20, \text{ and } r = 4\cdot5.$$

When $R - r = 6$, S = 51 tons.
= 12, = 65 tons.
= 18, = 72 tons.

Also when R is taken infinitely large, $R - r$ approaches the value R, so that $\frac{R - r}{R}$ becomes very nearly equal to unity.

Hence for an infinitely thick cylinder, the useful strength is T$r$, and in the case above this is equal to 90 tons.

Limiting pressure in homogeneous cylinder.

*If it is required to know whether a cylinder is sufficiently strong* to resist a given internal pressure, the force (P) exerted (p. 35) must be compared with the useful strength (S) given by Eq. (2), remembering that both sides must be taken into account.

Evidently in order that the cylinder may not burst, the splitting force must not be greater than the resistance of the metal.

$$\therefore\ 2pr \text{ must not be } > 2\mathrm{S}.$$

$$pr \quad ,, \quad ,, \quad \mathrm{T}r\,\frac{\mathrm{R}-r}{\mathrm{R}}.$$

$$p \quad ,, \quad ,, \quad \mathrm{T}\,\frac{\mathrm{R}-r}{\mathrm{R}}.$$

For an infinitely thick cylinder $\mathrm{S} = \mathrm{T}r$, and therefore for such a case $p$ must not exceed T.

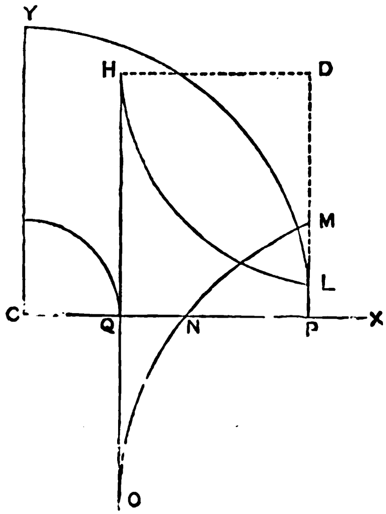
Hence no thickness of metal, however great, in a homogeneous cylinder can safely withstand a pressure greater than the tension which can be safely applied to the interior.

Waste of strength in homogeneous cylinder.

*To show the great waste of strength in a homogeneous cylinder*, Fig. 6 is introduced, in which as before—

C is a point on the axis.
CQ, the internal radius $= r$.
CP, the external radius $=$ R.
and CX and CY the axes of co-ordinates.

Fig. 6.



Then, if tension is represented by ordinates above CX, compression will be shown by those below that line.

The actual strength of the metal is represented by the area HDPQ and $= T (R - r)$.

The real useful strength according to Barlow is represented by HQPL, and $= Tr \left(\frac{R - r}{R}\right)$.

The difference between these or the area DHL, is the strength not utilised, and is evidently very large.

*Methods of obtaining increased strength.*

The question then arises, How should a cylinder be constructed so as to prevent this great waste of strength?

Method of obtaining strength.

Referring to Fig. 6, it will be seen that the object is to make such arrangements that when the internal pressure is applied, the stress on every layer shall be equal to that at Q. In other words, when the tension at Q is represented by QH, that at P must be equal to PD, QH being the greatest tension which can be safely applied to the inner layer.

This can be done by arranging the material so that the interior shall be initially under compression, and the exterior in a state of tension, as represented by the curve ONM, which shows that the particles between Q and N are initially in compression, while those between N and P are in tension.

Then, if the points O and M and the curve OMN have been properly chosen, when a pressure is applied such that the stress at Q changes from a compression OQ to a tension QH, the stress at P will change from a tension PM to a tension PD. At intermediate points along the line QP the stress will change from an ordinate to the curve ONM to an ordinate to the line HD. The useful strength of the cylinder will be represented by the area OHDMN. This method is known as "the system of initial tension."

Rodman system.

This system is exemplified by the Rodman smooth-bore cast-iron guns which were made by casting the piece hollow and cooling it from the interior, so that the inner portion is compressed and supported by the contraction of the other more liquid portions upon it while cooling. Thus the inner layers are in a state of compression and the outer under tension.

In the case of the Austrian Uchatius guns, rifled pieces are cast from a metal homogeneous at first as to material, but the several layers of which are, subsequently to casting in chill, placed in a state of tension as regards the exterior, and of compression as regards the interior, by driving through the bore of the gun a series of steel mandrils gradually increasing in size. Austrian Uchatius.

The inner layers are so made harder, and although a portion of their elasticity is overcome, and the amount of work which can be done on them is reduced, they are better supported by each of the outer concentric layers, and are given higher limits of elasticity and tenacity.

The most usual way, however, of making use of this system is to build up guns with hoops either heated and shrunk on, or forced on by hydraulic pressure.

In estimating the strength of a hooped gun Barlow's law is of little use, since it only takes into account an internal pressure, whereas in a hooped gun the hoops are under external as well as internal pressure. The formula usually made use of is that of Rankine, and will be found together with the proof on p. 290 of his "Manual of Applied Mechanics."* Strength of hooped gun.

Let $t =$ tension at any radius $y$.
$R =$ external radius.
$r =$ internal radius.
$y =$ any intermediate radius.
$p_0 =$ internal pressure.
$p_1 =$ external pressure.

Then $$t = \frac{p_0 r^2 (R^2 + y^2) - p_1 R^2 (r^2 + y^2)}{y^2 (R^2 - r^2)} \qquad (3.)$$

If $p_1 = 0$, we have the case of a homogeneous gun, and the equation becomes

$$t = \frac{p_0 r^2 (R^2 + y^2)}{y^2 (R^2 - r^2)} \qquad (4.)$$

a more correct result than that of Barlow.

Using this formula, Mr. J. A. Longridge has investigated† the gain of strength by hooping, and this theoretical result

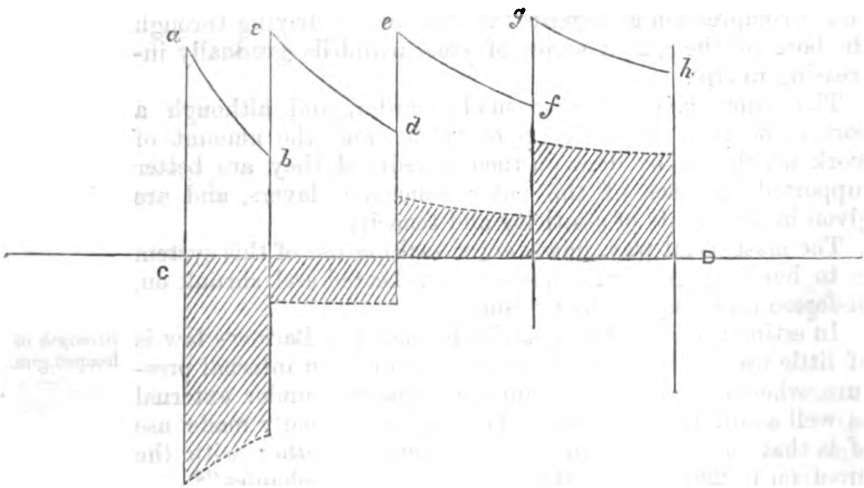
* See also "Traité d'elasticité," par M. Lamé.

† Proceedings of the Institute of Civil Engineers, vol. 19, p. 283, "On the Construction of Artillery." Also vol. 56, Part 2, "On the Construction of Heavy Ordnance."

Strength of hooped gun.

is shown in the annexed figure, in which ordinates below CD represent compression, and those above indicate tension.

Fig. 7.




The shaded parts represent the state of the cylinder before the internal pressure is applied, so that instead of a curve similar to ONM of Fig. 6, there are a series of abrupt changes, the two inner rings being in compression, and the two outer in tension. The state of the cylinder at the instant of maximum stress is shown by the upper lines; and the useful strength of the cylinder is represented by the area between the dotted and full lines.

In making use of equation (3) great caution must be exercised. It indicates theoretical possibilities, but a long series of costly experiments can alone confirm their truth or otherwise in practice.

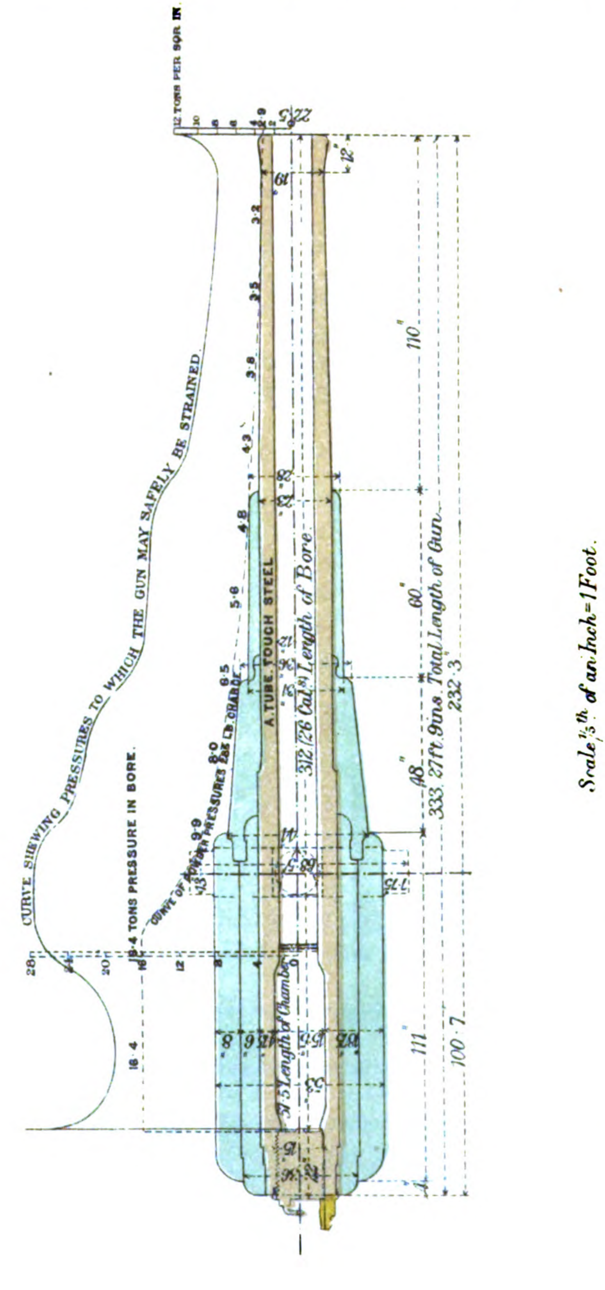
It is not known to what extent systematic experiments have been carried out by private gunmakers in this country or on the continent, but no reliable ones have, as far as is known, been published.

System of varying elasticities.

A strong cylinder can also be obtained by building it up so that the most extensible (within the elastic limit) material shall be in the interior, and the least on the outside of the gun.

If the elastic extensions regularly diminish from the interior outwards, and if the tension to which the several laminæ can be safely strained is the same in each, and equal to T, then any pressure which would strain the interior up to its elastic limit would also strain all the other laminæ up to their limits,

# A DESIGN FOR A GUN.




Scale 1/15th of an Inch = 1 Foot.

To face page 43.

and as before the whole strength of the metal QHDP will be utilized.

Another arrangement by which the whole available strength of the material can be theoretically utilised is to build up the cylinder of laminæ possessing different strengths, the strongest being placed in the interior, and the weaker on the outside, the strengths of intermediate laminæ following the law expressed by the curve HL in Fig. 6. System of varying strengths.

If the longitudinal stress is assumed to be transmitted according to the law of Barlow or of Rankine, the longitudinal strength can be approximated to by summing up the strengths of the narrow rings of which the cross section may be supposed to consist. This result should be compared with the force L, *p.* 36. An important point connected with this is that a single ring of metal near the exterior is in a better position for withstanding a given longitudinal pressure than a ring near the interior, because it is of greater length, and therefore of larger area. Longitudinal strength.

The opposite diagram, which does not represent any present or future service gun, shows the margin between the pressure due to the charge of powder and the working strength of the gun, which should be determined when a gun is designed. In calculating the curve of strength a large allowance is made for the suddenness of the pressure, &c., but in the present state of our knowledge of the strength of a hooped cylinder little reliance can be placed on these calculations. The curve of powder pressures, on the other hand, may be accepted as virtually correct for normal conditions. Curves of strength and pressure.

## Systems of Construction.

### *Armstrong.*

The principles of the present Armstrong construction are— Principles of Armstrong construction.

First, the material is arranged in the several parts so as best to resist the strain to which it is exposed. Thus the interior, where the stress is greatest, is of very strong and elastic steel, while the exterior is formed of coils of wrought iron with the fibre running round the gun, so as to be in the best position to withstand the circumferential tension. Again, the inner tube is solid ended, because the longitudinal strength of the gun depends almost entirely upon it, the wrought-iron coils being weak longitudinally.

Secondly, the wrought-iron coils are shrunk over the inner tube in such a manner that it is placed in a state of compression, while the coils are in a state of tension, the amount of tension being so regulated that each coil shall perform a fair amount of useful effect in resisting the pressure from within.

Armstrong construction.

This is done by calculating as closely as possible the initial strains which ought to be applied, and then making such an allowance that the second layer is somewhat more highly strained than by theory it ought to be. In like manner the third coil is more highly strained than the second. The effect of this is under the pressure of the powder gas the larger proportion of the strain is taken by the outer coils.

*Woolwich.*

Woolwich construction.

The system of surrounding a steel tube with wrought-iron coils has been adopted by the English Government, it being considered that a hard, strong, and elastic steel was the best material for the barrel, and that safety could be obtained by surrounding it by tough wrought-iron coils.

It should, however, be stated that the advantages of this method are not allowed by many authorities on gun construction, who contend that the difference in the elasticity of the steel and iron is a source of danger.

The present Woolwich construction differs from the Armstrong in that the gun is built up with one or two layers of long thick coils, instead of with a greater number of layers of short and comparatively thin ones. This increases the longitudinal strength, and as the trunnions form part of the breech coil prevents the breech being blown off as in the case of the Duilio's gun. The difference between the two systems of construction is seen by comparing the diagrams of the 100-ton and 80-ton guns.

Also it is not attempted rigidly to carry out the tension and compression of the several layers in accordance with actual mathematical calculations; but the coils are put on with sufficient shrinkage to ensure a certain amount of compression of the inner portion.

*Manufacture of Service Guns.*

Original.

The first M.L.R. guns introduced into the service were built on the original Armstrong construction, and consisted of an inner tube of steel or wrought iron, a forged breech-piece, with the fibre running along the gun and a series of thin coils hooked together. The 9-inch Mark I. may be taken as the type of this early construction. *See* diagram opposite.

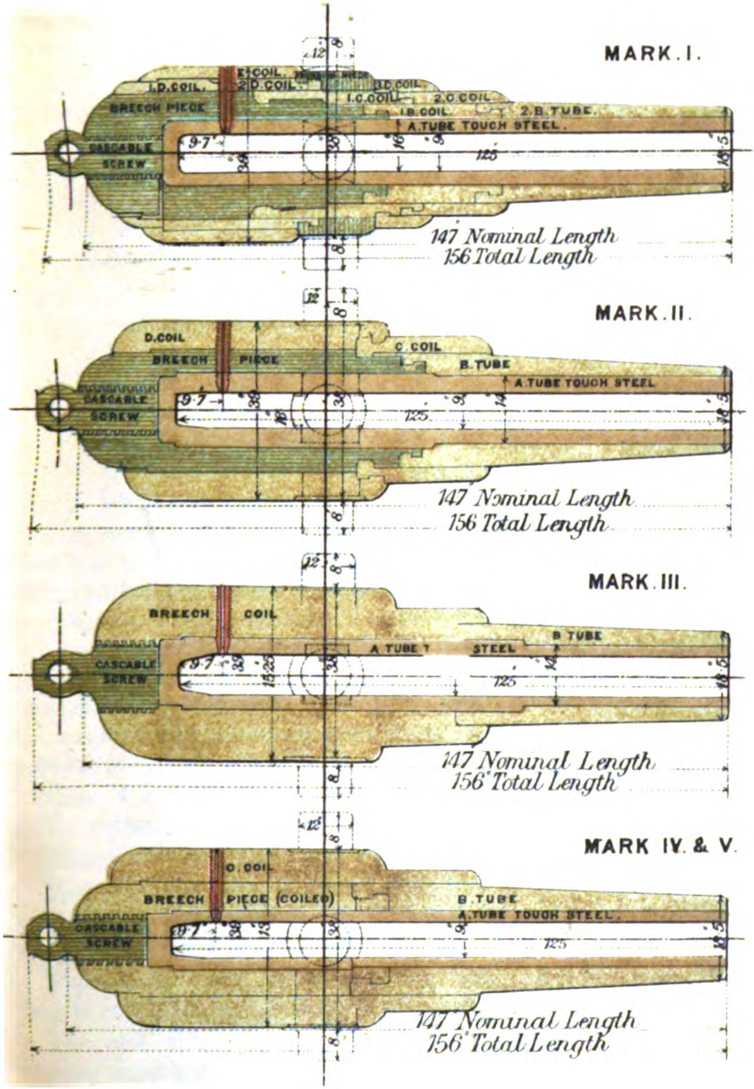
Fraser.

The next modification consisted in replacing the many thin coils by a few thick ones, and is represented by the 9-inch Mark II.

When wrought iron was abandoned for the inner tubes of built-up guns it was thought unnecessary to retain the solid

# WROT IRON RIFLED MUZZLE-LOADING 9 INCH GUNS OF 12 TONS.

*Scale $\frac{9}{32}$ Inch = 1 foot.*

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Dangerfield Lith. 22 Bedford St. Covent Garden

forged breech-piece, since the solid-ended steel tube would supply the necessary longitudinal strength. This led to the pattern represented by the 9-inch Mark III., in which the steel tube is surrounded by only one layer of coils. This arrangement was a considerable departure from theory, and finally it was thought advisable to return to two layers of coils over the breech, which is represented by the 9-inch Mark IV. Fraser.

A further modification has been introduced, and is now the pattern on which most service guns are constructed. It is represented in the diagram of the 80-ton gun, except that in smaller natures the B tube extends from the 1B coil to the muzzle.

This construction will now be described, the 7-in. Mark IV., the smallest gun made on this principle, being taken as the type. 7-in. mark IV. gun.

THIS gun consists of—

An inner barrel or tube of toughened steel (A tube).
B tube.
1 B coil or belt.
Breech-piece (coiled).
C coil or jacket.
Cascable.

The steel for the inner barrel is cast and afterwards forged. Casting is necessary, not only for the purpose of obtaining a sufficiently large block of steel, but also for making the block homogeneous and uniform in structure. Forging or drawing out the cast block imparts to it the desirable properties of great solidity and density. It is turned and bored to the proper size, toughened by heating and afterwards cooling in oil, and finally tested to 4 tons per square inch by hydraulic pressure. Steel tube.

The B tube is composed of two single and slightly taper coils, united endways, turned and bored. B tube.

These coils are made and welded as follows:—

The wrought iron is either rolled or forged into long bars varying in section from $2\frac{1}{2}$ to 9 inches or more, according to the purpose for which it is intended.

These long bars are placed in a long furnace, heated to a bright red heat, and coiled round an iron bar or mandril.

The coil thus formed is heated, and the several parts welded together under a hammer.

The 1 B coil is composed of a single coil, which after welding is turned and bored to the proper dimensions. 1 B coil.

The breech-piece is composed of two single coils, united together endways, then turned and bored. Breech piece.

C coil. The jacket is composed of a breech coil, trunnion ring, and ring coil, made and welded together as follows:—

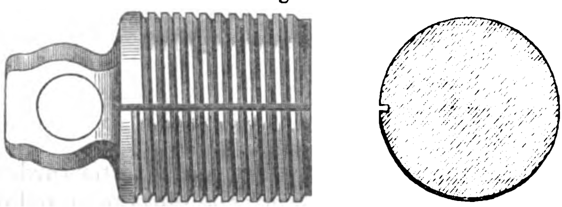
The trunnion ring is made by welding together slabs of iron, and then gradually converting the mass thus produced into a ring by punching a hole, which is gradually enlarged by a series of tapered mandrils increasing in size.

The breech and ring coils are formed in the usual manner.

After these pieces have been prepared for each other, the jacket is built up by placing the breech coil on its breech end, and then dropping the trunnion ring—previously expanded by heating—over it. The ring coil is then dropped on to the face of the breech coil, so that the trunnion ring forms a band over the joint and in cooling contracts and unites them firmly together.

Cascable. The cascable is made of wrought iron with a bevel thread cut on it as shown in the annexed sketch.

Fig. 8.



One round of thread is turned off the end, and a channel is cut across the thread, to form a gas escape, in case the steel barrel should split.

Sir W. Palliser points out that the thread of the female screw must be *plus* to the breech coil to prevent fracture at the last thread, as in the case of the "Wyvern's" gun, which blew its breech off in 1867. The principle involved is similar to that of the armour bolt.

Building up. The steel barrel and breech-piece, having been prepared for each other by turning and boring to corresponding dimensions, are shrunk together as follows:—

The breech-piece is heated until it is sufficiently expanded to fit easily over the breech end of the steel barrel, which is placed upright in a pit ready to receive it. The breech-piece is then raised and dropped over the steel barrel, up which a stream of water is forced to keep it as cool as possible during the process of shrinking.

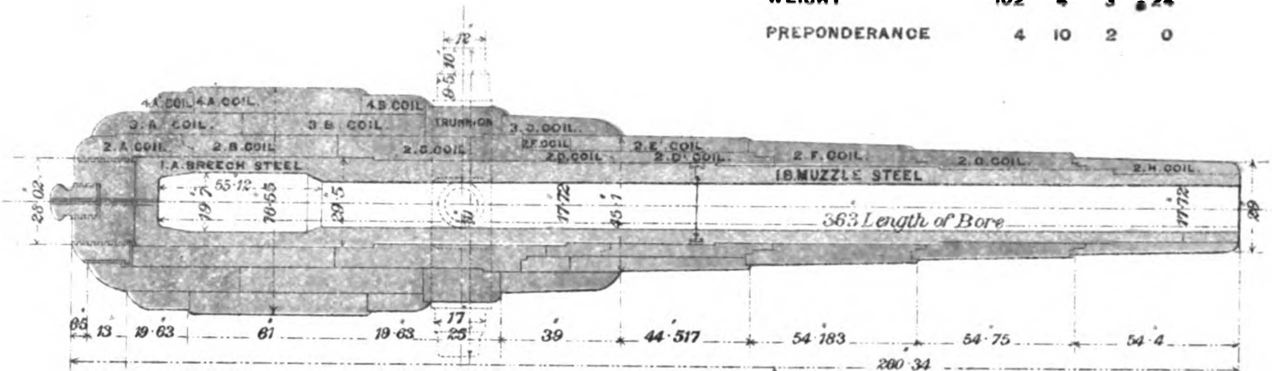
The cascable is now screwed in, great care being taken that it bears evenly against the steel tube, and to prevent it moving a plug is screwed in through the breech-piece.

After turning and boring to the proper size the 1 B coil and B tube are successively shrunk on in the same manner.

# ORDNANCE WROT IRON RIFLED MUZZLE-LOADING 17·72 INCH 100 TONS.

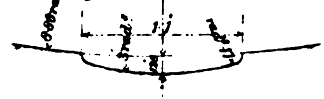
*Scale $\frac{3}{16}$ inch - 1 foot.*

| | TONS. | CWT. | QRS. | LB. |
|---|---|---|---|---|
| WEIGHT | 102 | 4 | 3 | 24 |
| PREPONDERANCE | 4 | 10 | 2 | 0 |




*Number of Grooves, 28.*
*Rifling, an Increasing twist of 1 turn in 150 Calibres at Breech, to 1 turn in 50 Calibres at 2·88 inches from Muzzle. To 2·88 inches a uniform twist of 1 turn in 50 Calibres.*

SECTION OF GROOVE.
$\frac{2}{3}$ FULL SIZE.

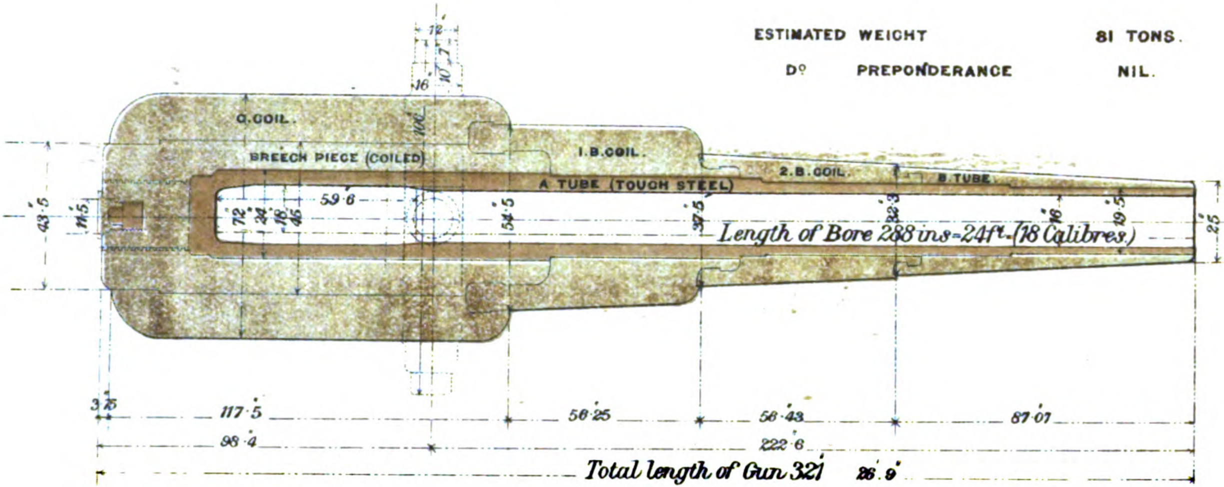



Face page 46.

# ORDNANCE WROT IRON RIFLED MUZZLE-LOADING 16 IN 80 TONS.

*Scale $\frac{2}{32}$ inch = 1 foot.*

| | | |
|---|---|---|
| ESTIMATED | WEIGHT | 81 TONS. |
| Do | PREPONDERANCE | NIL. |

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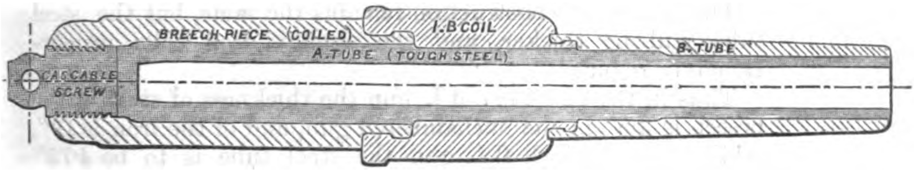
DANGERFIELD. LITH 22 BEDFORD ST COVENT GARDEN.

The partially formed gun having now a complete layer of coils over its steel tube is turned for the reception of the jacket, which is shrunk on in the same manner as the breech-piece. **Building up.**

Fig. 9.




For all minor details, as well as for particulars respecting the construction of the other service guns, officers are referred to the treatise on gun construction.

Diagrams, pp. 46, 47, and 48, show the construction and dimensions of some service guns.

The 100-ton and 80-ton guns are selected as being the largest yet made, while the diagram of the 9-inch gun shows the progressive change of manufacture.

A converted and some lighter guns are added, their construction being somewhat different from that of the heavier guns. The diagram of the 8-inch howitzer shows the form of a piece designed for high-angle fire.

TABLE showing the CONSTRUCTION of the VARIOUS MARKS of BUILT-UP M.L. GUNS, 64-prs. and upwards.*

| Nature. | Original Construction. | Fraser Modification with Forged Breech-piece. | Fraser Modification with One Layer. | Fraser Modification with Two Layers. | Remarks. |
|---|---|---|---|---|---|
| | Mark. | Mark. | Mark. | Mark. | * These are now the |
| 64-pr., 64 cwt. .. | I.§ | II.§ | III.*§ | — | service pat- |
| 7-inch, 90 cwt. .. | — | — | I.¶ | — | terns for fu- |
| 7-inch, 6½ or 7 tons | I.‖ | II.§ | III.¶ | IV.*¶ | ture manu- |
| 8 „ 9 tons .. | I.§ | II.‖ | III.*¶ | — | facture. |
| 9 „ 12 „ .. | I.§ | II.¶ | III·¶ | IV., V.*¶ | ‖ Iron |
| 10 „ 18 „ .. | — | — | I.¶ | II.*¶ | tubes. |
| 11 „ 25 „ .. | — | — | I.¶ | II.*¶ | ¶ Steel |
| 12 „ 25 „ .. | I.¶ | — | —* | II.*¶ | tubes. |
| 12 „ 35 „ .. | — | — | — | I.*¶ | § Some |
| 12·5 inch, 38 tons. | — | — | — | I.*¶ | with iron, |
| 16 inch, 80 tons .. | — | — | — | I.¶ | and some |
| 17·72 inch, 100 tons | — | — | — | — | with steel |
| | | | | | tubes. |

* Treatise on the construction of ordnance, 1879, p. 245.

B.L. guns.

*New Designs.*

Designs have been put forward and will probably be adopted for B.L. guns of 12, 10·4 and 9·2 inch; the details will be found in the tables p. (276).

The system of construction remains the same, but the steel tube will be thicker, and the wrought-iron coils proportionately reduced.

Thus in the 12·5 inch M.L. gun the thickness of steel at the breech is 3·5″ in the unchambered gun, and of the iron is 19″, while in the 12-inch B.L. gun the steel tube is to be 4·75″ thick over the chamber, with 14″ of iron.

The arrangement for closing the breech, which it is proposed to try, is a modified form of the French broken threaded screw, of which the details are given on p. 51.

*Palliser.*

Palliser system. Principles.

The Palliser system is based on the following principles:—

That the circumferential strength of a gun should be provided by the inner tube, while the longitudinal strength should be dependent on the exterior.

The inextensible cast-iron casing is lined by a wrought-iron tube which is very extensible beyond its elastic limit, so that when it is permanently extended by firing heavy proof charges, although a portion of its capacity for absorbing work is expended, yet its limit of elasticity is raised, and it is well supported by the cast iron.

Again, the more extensible material being next the bore enables a larger proportion of the stress to be transmitted to the exterior than would be the case in a homogeneous cylinder.

The strength of this system is shown by a late experiment with a 7-in. gun converted from an old 10-in. 95 cwt. gun by boring it out and then inserting a tube 3″ thick. This gun safely withstood five rounds double loaded, the last round being 22 lbs. P., 100 lbs. projectile, 14 lbs. P., and 85 lbs. projectile, with gas-checks and studs.

This system of construction has been adopted in the United States for 8 in., 10-in., and 12-in guns.

Method of converting a cast-iron gun.

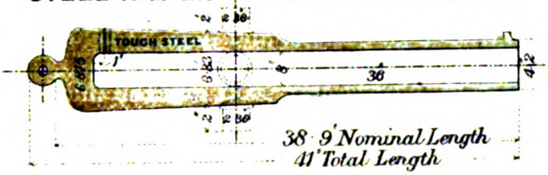
An 8-inch S.B. gun, see diagram, is first bored to 10·5″ diameter, and the muzzle is recessed and screwed for the cast-iron collar (the use of which is to keep the tube in position), and the gas channel is bored through the breech.

The A tube is formed of five coils of wrought-iron united together in the usual manner, and the recess in the breech cut and tapped for the wrought-iron cup. The cup for closing the breech end of the barrel is forged and stamped into shape

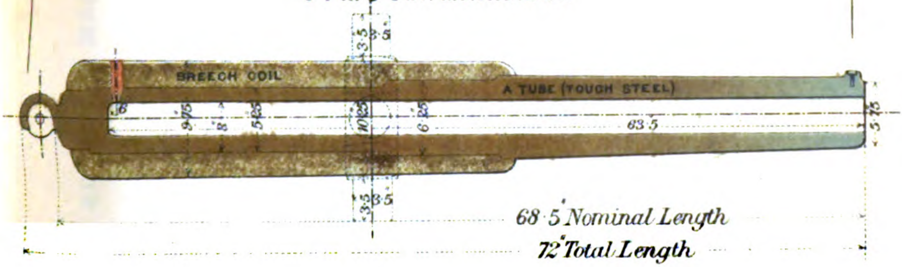
# R.M.L. ORDNANCE.

*Scale ¾ inch to 1 foot.*

## STEEL R.M.L. 7-PR. 200 LBS. MARK IV.

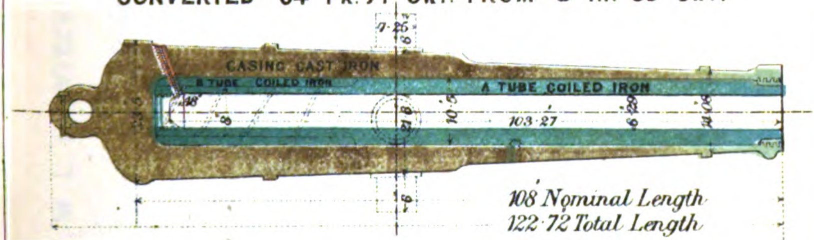



## 9 PR. 8 CWT. MARK. II. S.S.

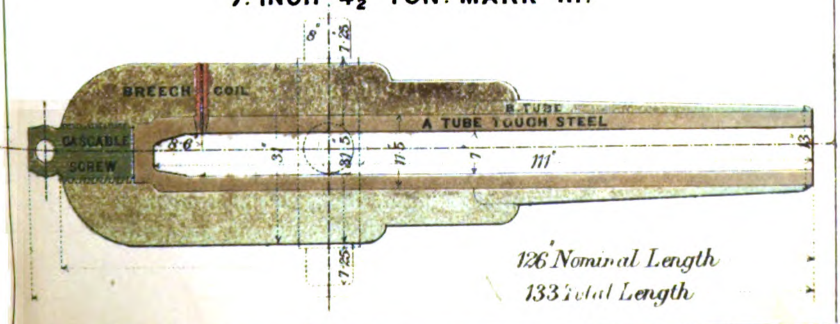



*Scale ⅜ inch to 1 foot.*

## CONVERTED 64 PR. 71 CWT. FROM 8 IN. 65 CWT.




## 7. INCH 4½ TON. MARK III.

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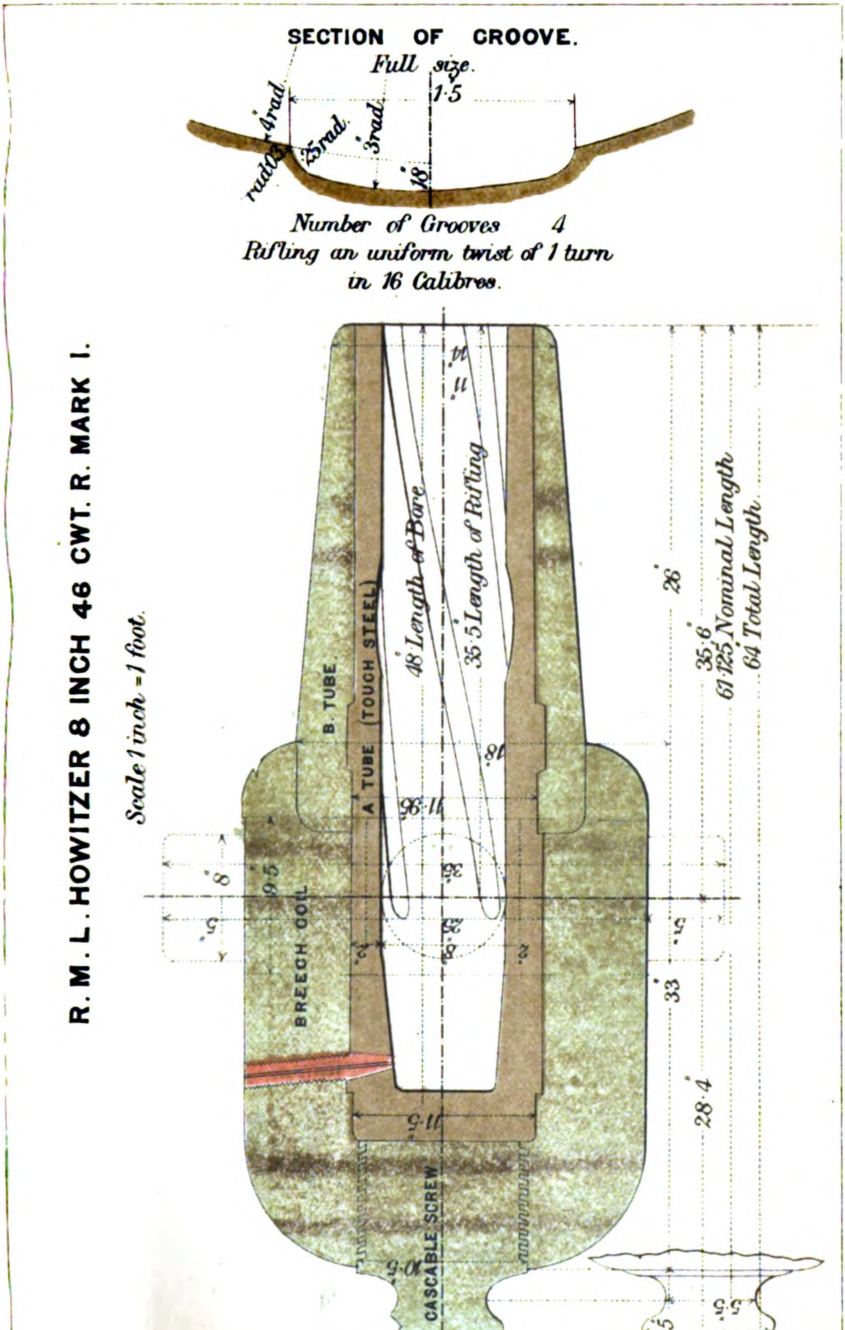
Dangerfield Lith. 22, Bedford St. Covent Garden.

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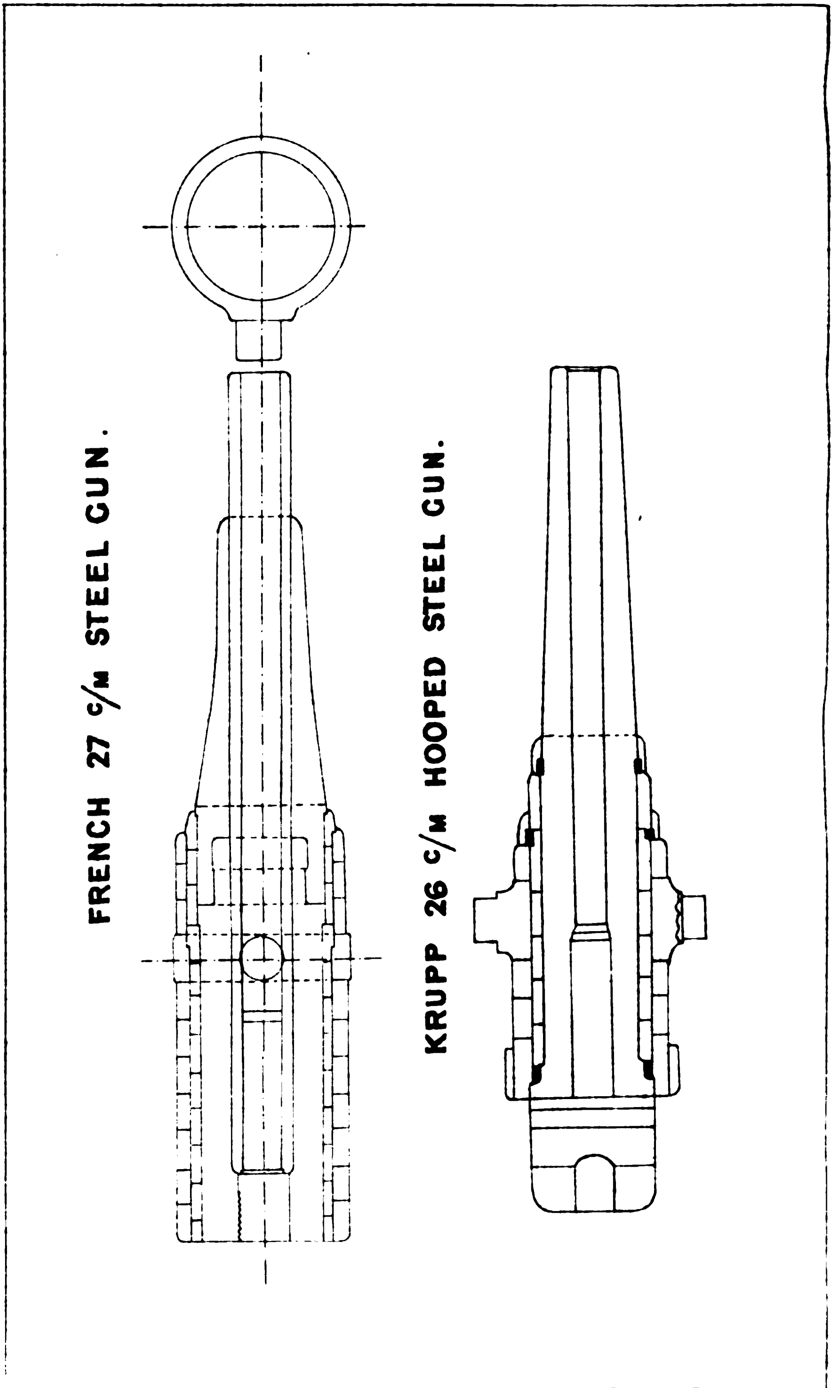
Dangerfield. Lith 22. Bedford St. Covent Garden




To face page 49

Dangerfield Lith. 22 Bedford St. Covent Garden.

under a steam hammer. It is turned inside and out, and screwed on the outside with a thread of five to the inch: it is then screwed tightly home. **Palliser's method of conversion.**

The A tube in this state is then tested with water pressure of 120 lbs. on the square inch. The breech end of the A tube is then turned over a length of 32″ to receive the B tube, and a spiral gas channel is cut round its exterior, communicating with star grooves cut in the end of the barrel and the gas escape through the cast-iron breech of the gun.

The B tube consists of two coils of wrought iron, and is shrunk in over the breech part of the A tube. The object of making the tube double at this part is that, in the event of the inner tube splitting, the outer may be available to prevent continuous rupture.

The tube is now fitted into the bore of the gun, the greatest care being taken that the breech end bears fairly against the cast iron. When the tube is properly adjusted, a cast-iron collar is securely screwed into the muzzle.

A hole is drilled through the cast-iron, and a short distance into the tube at 29″ from the trunnions under the chase, and, being tapped, a wrought-iron pin is screwed in to prevent the tube from shifting round.

## *Krupp.*

In the Krupp guns of recent models not only is steel used for the inner barrel, but the hoops are also of the same material. **Krupp.**

There are two broad classes, hooped guns and jacketed hooped guns.

A hooped gun (see Plate) consists of an inner tube and one or more layers of hoops. The 28 and 30½ c.m. guns have three layers of hoops, the 24 and 26 c.m. guns two layers, and the remaining hooped guns only one layer. The solid tube forming the principal part of the gun is the same length as the gun, and contains the wedge slot. Each layer of hoops consists of several hoops shrunk on to the gun, one in rear of the other. They are forged out of solid steel cylinders without a weld.

The jacketed hooped guns consist, 1st—of the inner tube, extending from the muzzle to the front of the wedge slot; 2nd, the jacket surrounding the rear of the inner tube, and containing the wedge slot; 3rd, the layers of hoops.

It is stated in the official "Ship and Coast Guns of the German Navy" that the strength of a hooped gun on this principle is from 1½ to 2 times as great as that of a solid gun of similar dimensions, while a jacketed hooped gun is 2 to 2½ times as strong.

*French.*

French.

The French heavy guns of the model 1870 consist of an inner steel tube with a cast-iron casing strengthened by steel hoops.

The steel tube is about one fourth of a calibre thick, and extends as far as the front of the trunnion ring; its rear end is threaded to screw into the cast-iron, which is expanded by heat to allow of its insertion.

The hoops are heated and shrunk on in one layer for the 14 c.m., and in two layers, breaking joints, in the larger natures. The thickness of the cast-iron casing is approximately three quarters of the calibre, and of the hooping about one half of the calibre.

Guns built up entirely of steel of the model 1875 are, however, now under trial, and the general arrangement of these is shown in diagram (p. 49).

BREECH-LOADING SYSTEMS.

Requirements.

The next question which has to be dealt with is, shall the gun be made to load at the breech or at the muzzle?

This matter is entirely separate from the general construction of the gun, since with the systems of building up introduced by Krupp, Armstrong, and others, the guns can be equally well made either B.L. or M.L.

The answer to the question depends upon—

1. The efficiency of the breech-closing arrangement.
2. The shooting of the gun.
3. The facility with which the gun can be worked under the varying conditions of—
    *a.* Broadside.
    *b.* Turret.
    *c.* Boat.

*Breech-closing arrangement.*

Efficiency.

The efficiency of any particular arrangement depends upon—

*a.* Whether the gun can be fired without the breech being closed.

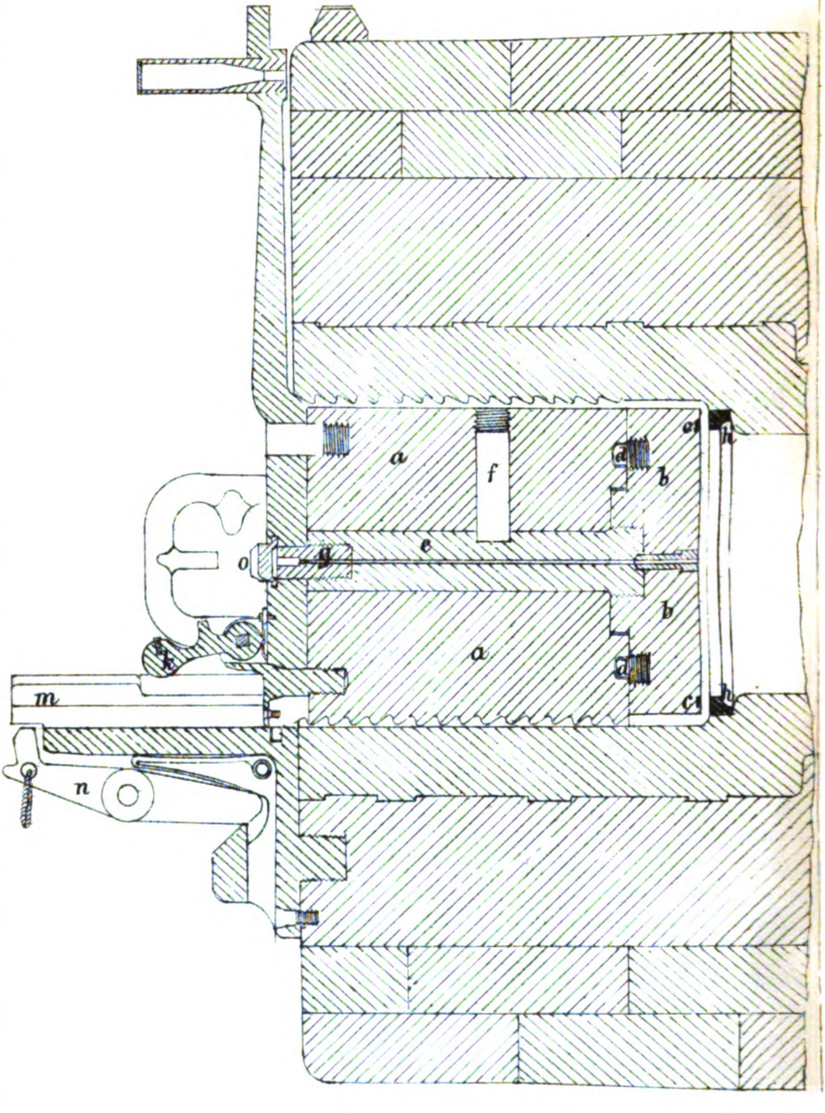
*b.* Whether the apparatus is strong enough and acts as an efficient and durable obturator.*

*c.* Whether it can be handled easily and quickly without danger of getting out of order or of being injured by the fire of the enemy.

The principal breech-closing arrangements will now be described with a view of ascertaining whether these conditions

* The word "obturator" is used to describe that part of the breech-closing arrangement which prevents the escape of gas; the term gas-check, which is sometimes used, has another meaning in our service.

# FRENCH BREECH CLOSING SYSTEM




*To face page 51.*

are satisfied, remembering, however, that a system which may answer well with small guns may not be equally efficient when applied to heavy ordnance.

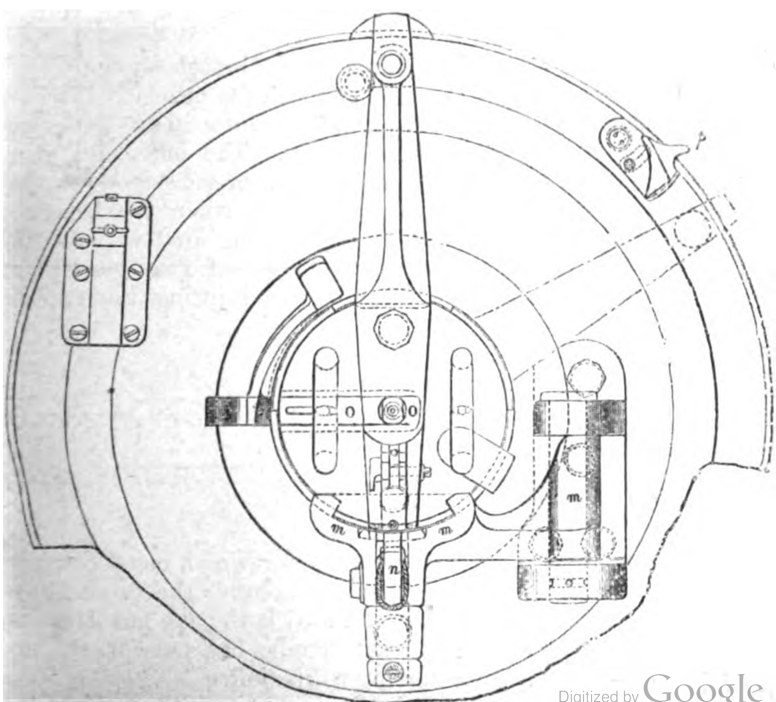
The original Armstrong system is so well known that there is no necessity for any description, and it will be sufficient to point out that neither of the above conditions is satisfied. Service Armstrong.

The system of breech-closing fitted to the French naval guns has, with certain modifications, been in use for many years, and as far as is known has given good results. French.

The breech is closed by a screw plug, which is screwed into the rear part of the bore. Were it necessary in firing to screw and unscrew the whole length of the plug at every round much time would be wasted; but this is obviated by planing out from both plug and breech three longitudinal grooves, each one-sixth the circumference, so that by placing the remaining portions of the male screw in line with the plain grooves in the female screw, the plug can be pushed home, and one-sixth of a turn being given to the plug by means of a handle attached to it, the breech is closed.

The general arrangement is shown in Fig. 10, and in the diagram opposite.

FIG. 10.



Breech screw. The breech screw ($a$) is of steel with a hole down the centre, a lever for screwing it up, and handles for withdrawing it.

Steel plate. The steel plate ($b$) fits on the front of the breech screw. On its front face is a fluted copper ring ($c$ $c$), which takes against the gas-check. On its rear face are two gudgeons ($d$ $d$) which fit into holes on the face of the breech screw, and prevent it turning round. A hole is pierced through the centre, which in front is bushed with copper, and in rear is screwed to receive—

Steel spindle. The steel spindle ($e$), which has a groove cut in it to receive the pin ($f$), which passes radially through the breech screw and keeps the plate and bush in place.

Steel bush. A steel bush ($g$) is screwed into the breech screw behind the spindle.

Obturator. The obturator ($h$ $h$) is made of copper and is fixed in its place.

Cradle. A bronze cradle ($m$) is hung by means of a strong vertical hinge, so that it can be placed in line with the bore to receive the breech screw, which is held in position by two ribs on the cradle fitting into notches in it, and by a catch ($n$) which comes into action as the cradle is swung to the side.

Firing arrangement. The firing arrangement consists of—

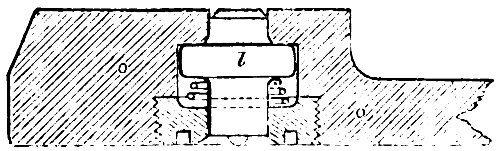
The vent, which is axial and passes through the steel spindle and the centre of the steel plate;

The hammer ($k$), which is fixed to the breech screw;

The percussion pin ($l$), Fig. 11, which fits into—

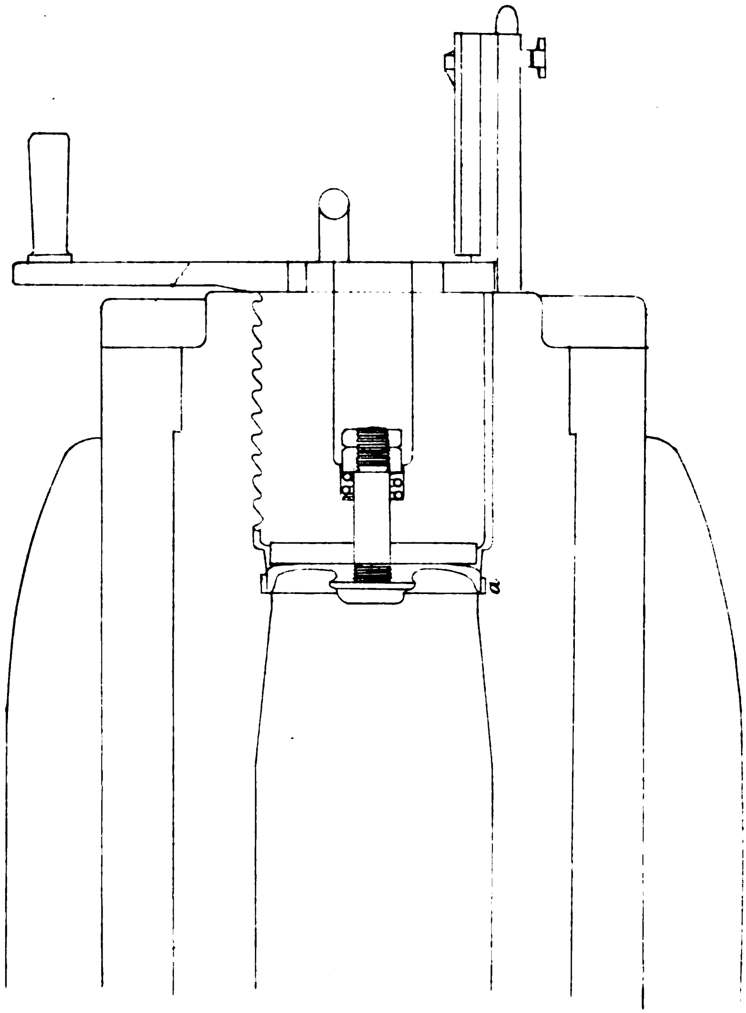
The bolt ($o$), Figs. 10 and 11. This slides in an under-cut groove on the rear of the breech screw. The outer end takes into a groove eccentric to the centre of breech screw, so that the percussion pin is only over the vent when the breech is screwed up. This prevents the gun being fired without the breech being closed, and stops all escape of gas, thus saving the vent and avoiding the possibility of injuring the captain of the gun.

FIG. 11.




To prevent the breech becoming unscrewed a metal catch ($p$) Fig. 10, is placed on the right side of breech; this catch lifts as the lever handle reaches it and allows it to pass, but drops by its own weight as soon as the handle has passed, and thus prevents the lever from moving to the left.

## ARMSTRONG BREECH CLOSING SYSTEM.




*To face page 53.*

DANGERFIELD LITH 22 BEDFORD S<sup></sup>T COVENT GARDEN

To load, the cradle is placed in line with the bore, and the breech plug unscrewed by moving the lever handle through a space equal to one-sixth of the circumference of plug; it is then drawn out of the bore on to the cradle, which is afterwards swung round at right angles to the bore; an iron bearer is then placed as a prolongation of the bore, and kept in the proper position by means of a short square stud which fits into a slot in the carriage. The projectile is placed on this bearer and pushed into the bore; and the cartridge is then entered and pressed home; the bearer is removed and the cradle swung round in line with the bore; the breech plug is then pushed in, and screwed up by means of the lever handle. Method of loading.

With reference to the conditions mentioned above, (*a*) is fulfilled, and no data are available as regards (*b*) and (*c*), but this system, having been in use for many years without much modification, is probably reliable.

The new Armstrong system has been fitted to guns up to 40 tons, and is to be used for the 100-ton breech-loaders ordered for the Italian navy. The general arrangement is similar to that just described, the only difference being in the breech plug and obturator. Armstrong broken-threaded screw plug.

The latter consists of an elastic steel cup fixed on the end of the breech plug, as shown in the diagram opposite. The end of the plug being slightly curved, the pressure of the gas forces the cup tight against the copper ring (*a*) in the diagram, so that all escape of gas is prevented. This cup can be shifted when required. This plan is to be tried with a view to its adoption for the new service B.L. guns.

The Krupp single wedge is the arrangement in use for all German naval guns, except the 8-centimetre boat, which has the double wedge. Krupp single wedge.

The wedge is either cylindro-prismatic or flat, but as the former is used for all guns of 21 centimetres and upwards, the latter will not be described.

The front of the wedge slot is flat and perpendicular to the axis of the bore; the back is semi-cylindrical. The rear face is at angle of about 1° 55′ to the front face, the slot being wider on the left than on the right. Wedge slot.

The principal parts are as follows:—

The wedge.
The wedge-plate.
The traversing screw with half bush.
The locking screw and bush.
The lever handle.
The Broadwell ring and steel plates.
The vent.

The wedge, Figs. 12, 13 and 14, has the same general Wedge.

edge.

shape as the slot, that of a cylinder, with a prism attached to it in front, and diminishes in thickness from left to right.

FIG. 12.

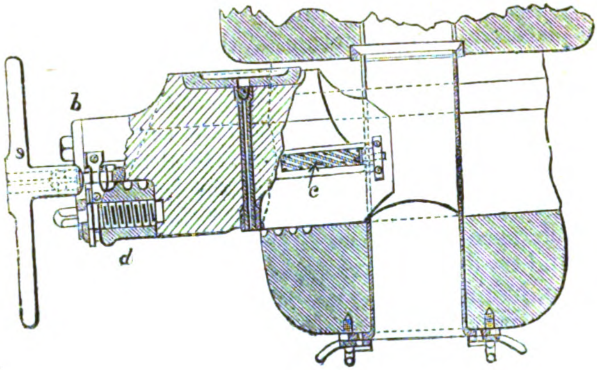
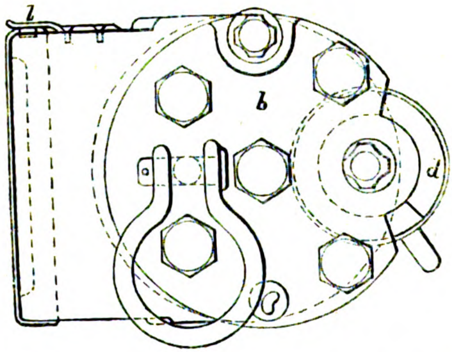


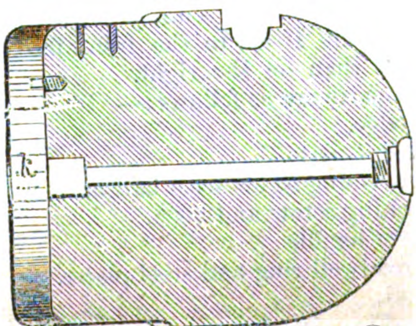

FIG. 13.




Wedge-plate.

The wedge-plate (*b*) in Figs. 12 and 13 is secured to the wedge.

FIG. 14.



The traversing screw, Fig. 15, is attached to the wedge at its point and neck respectively by a cap and cap-square. It moves the wedge in the slot, and has a right-handed screw which works in a female screw in the half bush which **Traversing screw.**

FIG. 15.

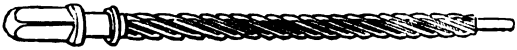
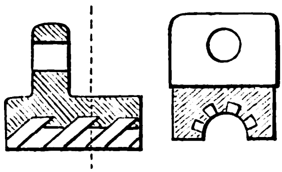


FIG. 16.

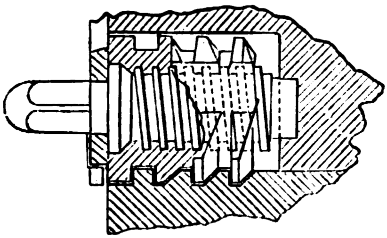


fits into a recess in the top of the wedge-slot, on the left side, and is secured to the gun.

The locking screw, Fig. 17, presses home the wedge for firing, holds it during firing, and loosens it afterwards. **Locking screw and bush.**

It (together with the bush *d*), Figs. 12 and 13, fits into a cylindrical recess cut in the back of the wedge on its left side, in such a position that two-thirds of the circumference of the recess are in the wedge, the remaining one-third being in the slot. The bush fits over the screw, and has four circumferential rings, of which the three on the right have about one-third of their circumference cut away, but the left one is complete and is fitted with a projection, which is allowed a motion of 120°.

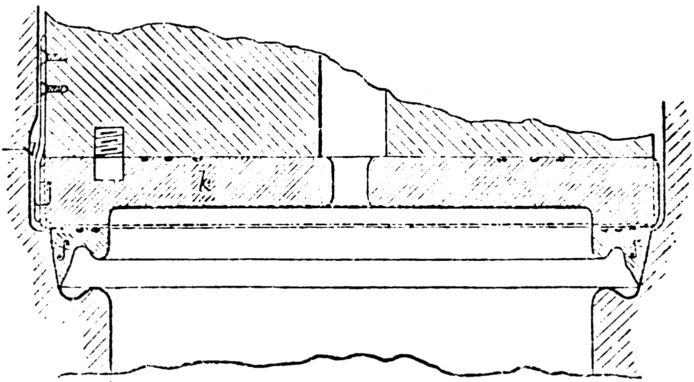
FIG. 17.



The Broadwell ring *f*, Fig. 18, is a steel ring of the section shown in the figure. It fits into a recess at the back of the powder chamber. The powder gas on firing presses the flat sur- **Broadwell ring.**

Broadwell ring. face of the ring against the steel plate, and the edge against the walls of the recess.

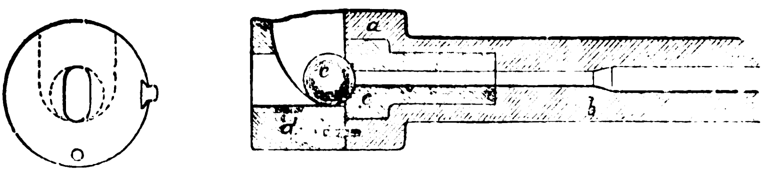
Fig. 18.




Steel plate. The steel plate ($k$), Figs. 14 and 18, is a thick circular disc projecting beyond the front of the wedge, to collect the fouling. It is very necessary to have a gas-tight joint between ring and steel plate; if, therefore, the former from an enlargement of its recess has become loose and moved to the front, the plate also must be pushed to the front. Thin brass discs are supplied for this purpose, and are laid behind the steel plate.

The vent is axial, is contained in a steel bush, and is provided in front with a ball gas-stop.

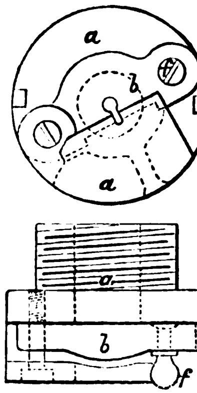
Fig. 19.




Axial vent with ball gas-stop. The steel bush has a shoulder ($a$) in front. A copper bush ($c$) is pressed into the front of the steel bush. The ball gas-stop is intended to stop the rush of gas to the rear sufficiently to prevent the gun detachment from being injured. It consists of the ball chamber ($d$) and the ball ($e$). The first is a cylinder hollowed out as shown in the sketch, and has an oval hole in front. When the powder gas penetrates this hole it drives the steel ball against the front of the

vent and closes it. The flash from the tube drives the ball upwards, so that it does not hinder the ignition of the charge. The bush projects to the rear and to it is screwed the tube catcher which retains the friction tubes after firing, and is composed of the plate ($a$) and the hasp ($b$). Ball gas stop.

FIG. 20.




The gun practice of the navy has shown that the ball vent bushes remain serviceable for at least 50 rounds in the larger calibres (24 c. m. and upwards), for about 100 rounds in the medium calibres (17 and 21 c. m.), and for more than 100 in the smaller calibres.*

To close the breech the lever handle is placed on the square of the traversing screw and turned to the right. As the bush is a fixture in the wedge slot, the traversing screw moves to the right; the left (outer) collar comes in contact with the recess and communicates the motion to the wedge. After about 1¾ turns the right collar touches the half-bush and checks further motion. To get the wedge completely home the locking screw must be brought into play. The lever handle is therefore placed upon it, and turned to the right. The bush follows the motion till its projection comes in contact with the slot in the bottom of the wedge plate. Its rings now lie in the corresponding grooves in the wedge slot. A further turning of the lever handle now pushes the screw to the right. The point of the screw touches the bottom of its recess and pushes the wedge more to the right, till the wedge plate comes Manipulation of the breech mechanism.

* Extracts from the Drill Regulations for the Prussian Artillery, &c., August 1878, p. 172. Translated by Major Ellis, R.A.

in contact with the left ring. When this occurs, the breech should be completely closed, *i.e.*, the steel plate and gas-check ring should be pressed together with a certain amount of force.

Breech mechanism of guns of 17-centimetre calibre downwards.

The cylindro-prismatic breech-closing arrangement of the guns of 17-centimetres calibre downwards, differs from that above described in that there is no traversing screw, and that the lever handle is keyed to the locking screw, the end of which is cylindrical instead of square.

With reference to the conditions *a*, *b*, and *c*, it may be remarked,—

Safety.

*a*. An arrangement has been fitted to some of the guns provided with the wedge breech arrangement which prevents the tube being inserted until the breech is closed.

Strength and durability.

*b*. Major-General Younghusband, C.B., R.A., in a report dated 9th November 1878,* remarks on the firing of 35·5 c. m. Krupp gun. At the conclusion of firing 30 rounds the breech mechanism appeared in perfect order, and there was no perceptible wear on either the ring or facing plate of the wedge.

The official report on the experiments at Meppen in 1879, remarks with reference to the 40 c. m. (70·8 ton) gun:—

" With regard to the particular system of closing the breech in use with all Krupp guns, it appeared to us perfectly efficient as far as strength and complete sealing of the bottom of the bore was concerned."

The Prussian Drill Regulations, p. 172, states:—

" A long 15 c. m. hooped gun fired 1,400 rounds (18·74 lbs. charge and chilled shell) with the same Broadwell ring. After 300 and 780 rounds there were signs of guttering, which were repaired by hammering out. . . . . ."

" A 28 c. m. hooped gun was perfectly intact after 400 rounds, with the exception of scoring over the seat of the shot . . . . The durability of the gun was in nowise affected thereby. . . . The obturator and working of the breech apparatus remained perfect."

Facility of working.

*c*. The time taken to withdraw the wedge of the 40 c. m. gun is 50 seconds. In the trials at Meppen in 1879, it was observed that after a few rounds the difficulty of starting the wedge was not inconsiderable. More than once the short lever proved insufficient to move the screw, and a longer one had to be applied, and occasionally the help of a third hand

* Report on Experiments with Krupp guns, &c., at Bredelar and Meppen, Jun and July 1878.

had to be called in to enable the two proper numbers to withdraw the breech block. No case came under observation of any of the working parts getting out of order.

### *Shooting.*

Whether a gun loads at the breech or muzzle the accuracy of the shooting depends, supposing the rifling and length of bore to be the same, on the windage being suppressed, the projectile being properly centred, the uniformity of the powder, and the space occupied by it being the same for each round. Shooting.

It is very generally admitted that it is easier to carry these out with B.L. than with M.L. guns, but it is claimed on the part of the latter that if the guns and ammunition are otherwise the same no material difference exists between them in this respect.

Reference to the tables, pp. 272–291, will show the relative efficiency of existing B.L. and M.L. guns.

### *Working.*

From our own experience with M.L. guns, it is known that existing M.L. guns up to the 25-ton can be worked with ease and facility, but it is equally certain that longer guns could not be worked in existing ships on the broadside if they are to be loaded at the muzzle. General question.

There is no doubt that B.L. guns can be worked without difficulty. For speaking of the Krupp guns, General Younghusband remarks:—

"The most noticeable feature in the Krupp 35·5 c.m. gun is the ease with which it is worked by manual labour alone and by a very moderate number of men. This is due to its being a breech-loader, for it may fairly be said to be impracticable to work a muzzle-loading gun of power equal to it, without steam, . . . ."

Again, when speaking of the same gun, he remarks:—

"Each round occupied from four-and-a-half to five minutes, but firing could, no doubt, be maintained much more rapidly, as all the operations were performed without haste. The wedge required about one minute to screw up."*

The Admiralty official report on the experiments in 1879, speaking of the 35·5 c.m. gun, says:—"The shot took 44

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* Report on experiments with Krupp guns, &c. at Bredelar and Meppen, June and July 1878.

General question.

"seconds to hoist into position. Raising the shot and ramming home, 1 minute. The whole operation of loading without laying for the target, 1 minute 46 seconds."

Under the most favourable conditions of ample room it seems to be probable that M.L. guns up to 25 tons would have the advantage as regards rapidity of working by hand, since, although they may have to be run in to the loading position, yet they have not the disadvantage of the two operations of opening and closing the breech. But, as before remarked, there is not ample room in existing ships.

Turret.

Heavy turret guns, whether B.L. or M.L., can probably be more effectively worked by machinery than by hand.

It therefore becomes a question whether a breech-loader or a muzzle-loader can be most effectively worked by machinery.

Now with either M.L. or B.L. the loading has to be performed outside the turret, and therefore uncontrolled by the officers inside, which is a source of danger with the former as evidenced by the accident in H.M.S. "Thunderer."

On the other hand, the B.L. does not suffer this disadvantage, as the danger of double loading is removed, but the smoke entering the turret, when the breech is opened, would probably impede the working.

Should the machinery break down, the B.L. would have the advantage, since it can be more easily worked by manual labour.

Broadside.

The disadvantages attending M.L. guns on the broadside are—

1. The ports must be lowered while loading to protect the loading numbers.

2. The decks are encumbered by the long slides required to allow the guns to be placed for loading.

3. Long guns cannot be used. This last consideration renders the introduction of B.L. guns inevitable, since high velocities cannot be obtained, as far as we know at present, from short guns.

The B.L. gun also possesses the immense advantage that the recoil can be reduced to a minimum, so that the mounting can be simplified and the working of the gun made easier.

Boats.

In boats, longer M.L. guns than those now in use could not be worked without further encroaching on the small space in the boat. So that B.L. means a more powerful armament for boats as well as for ships.

*Summary.*

The B.L. question from the naval view may be summed up thus:—

It is possible to construct B.L. guns of large size, of which the breech-loading apparatus will withstand the stress of firing heavy charges of a suitable powder.

B.L. guns can be made to shoot with great accuracy.

Longer, and therefore more powerful, B.L. guns can be worked on the broadside and in boats.

The loading numbers are not exposed.

The bore can be more easily examined, so that there is little danger of a premature explosion from burning fragments left from the previous round.

The gun cannot be double loaded.

The difficulties of chambering are reduced.

On the other hand, so far as the gun alone is concerned the M.L. is undoubtedly simpler than the B.L., as considerable care is required to keep the breech-closing arrangement in proper order, but when the means of working the gun is also considered this objection loses much weight, since in either case this machinery is complicated, but can probably be made more simple and efficient with a B.L. gun.

# CHAPTER III.

## CARRIAGES AND SLIDES.

### Principles.

The machine on which the gun is mounted is for naval purposes of equal, if not greater, importance than the gun itself. The most perfect and accurate piece of ordnance is of little use if it cannot be handled effectively, and this depends almost entirely on the efficiency of the mounting.

Requirements.

The requirements of naval mounting are:—Machinery, by which the gun can be elevated and trained up to the instant of firing; self-acting controlling gear, by which it shall be held, before, during, and after firing under all conditions of the sea; strength to resist the shock of discharge, and a break or arrangement for overcoming the recoil arranged in such a manner as to act in the most direct and uniform manner. At the same time the total weight of the gun and mounting must not be excessive, always remembering that increased rapidity of fire will justify an addition to the weight.

It will only be necessary to discuss the modern carriage mounted on a slide, the common truck carriage being utterly and hopelessly inadequate for the present requirements of the navy.

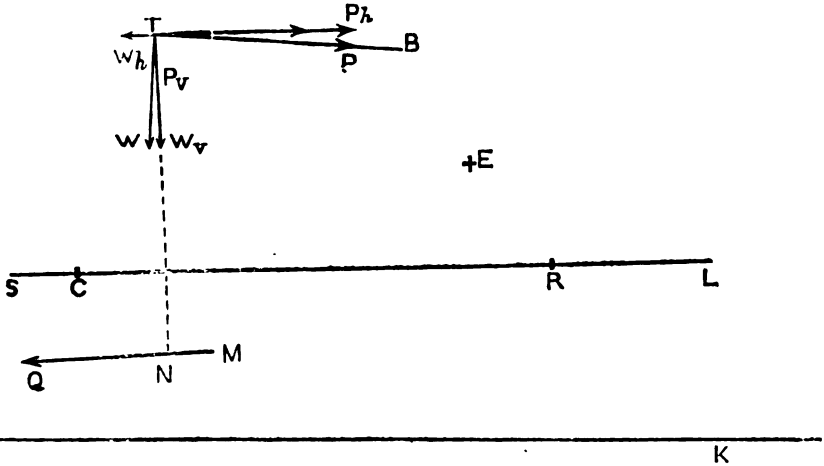
The general principles which should govern the form and arrangement of the mounting, and the material employed, will first be considered. After which particulars will be given of the various mechanical appliances for absorbing recoil, and for loading and working the gun, together with a description of various systems of mounting.

### *Effect of discharge.*

Effect of discharge.

The discharge may be considered as simply producing a force acting on the bottom of the bore in line with the axis of the gun, and in a vertical plane.

FIG. 1.




Effect of discharge.

In Fig. 1 let—DK be the deck,
SL the slide,
CR the extreme points where the carriage and slide are in contact,
T the centre of the trunnions,
B the bottom of the bore,
E the centre of the elevating pinion, and
M the centre of the compressor plates.

It will be only necessary to consider that part of the pressure which is transmitted to the carriage by means of the points of attachment, T the trunnions and E the elevating gear. If the gun have no preponderance and no play in the trunnion bearings, and the force act direct along TB, the whole will be transmitted at T.

Let P be the force under these hypotheses, and resolve it into two others,—the one $P_h$ parallel, and the other $P_v$ at right angles to the slide.

Similarly resolve the weight W of the gun, which in this case also acts at T, into two forces $W_h$, $W_v$, respectively, parallel and at right angles to the slide.

Again let Q represent the force at M, parallel to the slide, due to the action of the compressor, then the forces acting will be at T, the sum of the resolved components $P_v$ and $W_v$, tending to break the slide across, and necessitating the I form for the side of the slide; also a couple, represented by $P_h - W_h$, at T, and Q

at M, acting at an arm TN, tending to turn the carriage about R, raising the fore part at C and bringing a severe strain on the front clip plates, and a cross strain on the brackets of the carriage.

Hence the great reason for having low carriages, in which the arm of the couple is short, and the great advantage of the arrangement shown in Fig. 9, in which the hydraulic buffer is placed in line with the trunnions.

Effect of preponderance.

If the gun have preponderance, and the motion of the centre of gravity on recoil be not along the line joining the centre of the trunnions and the centre of gravity, the gun will tend to rotate round the trunnions, which will bring a strain on the elevating gear, the force being transmitted to the carriage through two points instead of one. Hence one disadvantage of preponderance in a gun.

For the sake of clearness the weight of the carriage acting at its centre of gravity has been neglected.

Conclusions.

From the above it will be seen that to reduce the shock between the gun and carriage, the former should have no preponderance and the trunnions should fit accurately; while to minimise the blow between the carriage and slide, the former should be low, so that it may always slide smoothly, and the latter should have vertical strength. The whole energy of recoil will then be absorbed either by the break or by the slide being inclined.

To meet any additional strain resulting from an increase in the muzzle energy, it will be necessary—

*a.* Either to increase the weight of the material used;
*b.* Or to arrange the material in a more efficient way;
*c.* Or to use a stronger material.

As regards (*a*), any increase in weight is objectionable.

From what has been said it would seem probable that an improvement can be effected in (*b*), and also in (*c*) by a more extended use of steel.

*Recoil.*

Velocity of recoil.

To find the maximum velocity and energy of recoil.

Let $W$ be the weight of gun and carriage,
$V$ the maximum velocity of recoil,
$w$ the weight of projectile,
$w'$ the weight of charge of powder, and
$v$ the muzzle velocity of projectile.

Then, if the momentum of the gun and carriage be taken equal to the momentum of the projectile and charge

Maximum velocity of recoil.

$$W V = (w + \beta w') v. \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

Where $\beta$ is a constant to be determined by experiment.

The maximum velocity of recoil is not attained when the projectile leaves the muzzle, because the gases continue to act on the bore for a certain time longer.

In an experiment quoted in the "Revue d'Artillerie," Vol. XIII., p. 440, as carried out with the 24 c.m. gun, it is stated that—

| | | |
|---|---|---|
| The velocity of recoil when the projectile left the bore was - - - - | 12·46 | f.s. |
| The maximum was - - - - | 17·06 | „ |
| Weight of gun - - - - | 34,400 | lbs. |
| „ carriage - - - - | 6,172 | „ |
| „ projectile - - - | 307·5 | „ |
| „ charge - - - - | 61·75 | „ |
| Muzzle velocity - - - - | 1,483 | ft. |

which gave a value of $\beta = 2{\cdot}4$.

Energy of recoil.

The energy (p. 96) of recoil is $= \dfrac{W V^2}{2g} \quad . \quad . \quad . \quad . \quad (2).$

$$= \frac{W}{2g} \cdot \frac{(w + \beta w')^2 v^2}{W^2} \ . \ . \ . \text{ from } (1).$$

and if the weight of the charge is $\frac{1}{m}$ lbs. the weight of the projectile

$$w' = \frac{w}{m}.$$

$$\therefore \text{energy of recoil} = \frac{wv^2}{2g} \cdot \frac{w}{W} \cdot \left(1 + \frac{\beta}{m}\right)^2 \ . \ . \ . \ . \ (3).$$

If $\frac{\beta}{m}$ in equation (3) be assumed constant (which is very nearly the case when similar guns are fired with charges of powder having the same proportion to the weights of the projectiles), then

$$\text{energy of recoil} \propto \frac{wv^2}{2g} \times \frac{w}{W}$$

Energy of recoil.

or Energy of recoil $\propto$ muzzle energy of projectile $\times \frac{w}{W}$;

so that if the muzzle energy of the projectile is constant, the energy of recoil varies *directly* as the weight of the projectile and *inversely* as the weight of the gun and carriage. It is clearly desirable to make the muzzle energy of the projectile a maximum, and to reduce the energy of recoil as much as possible consistent with the requirements of the particular gun.

The energy of recoil may be reduced either by decreasing the muzzle energy of the projectile, by increasing the weight of gun and carriage, or possibly by varying the powder. If the muzzle energy of the projectile is reduced the power of the gun is diminished; if the weight of the gun and carriage be much increased, a greater weight must be allotted to the armament in any particular ship. Each of these courses is objectionable, and it becomes necessary to resort to mechanical or other means for checking the recoil.

## COMPRESSORS.

Compressors.

The mechanical arrangements for controlling recoil are called compressors or brakes, of which there are two broad classes:—

1. Frictional.
2. Hydraulic.

Requirements of a good compressor.

A good compressor should fulfil the following conditions:—

1. It should come gradually into action, so that everything in the nature of a blow on the carriage or working parts is avoided.
2. The resistance offered should be low and should remain nearly constant.
3. It should be possible to adjust the compressors for any required length of recoil which should be maintained the same under all circumstances at every round.
4. It should be automatic.
5. It should hold the carriage when the ship is rolling, but should not interfere with running in and out when required.

### *Frictional.*

The two service forms of the frictional compressor are the Bow and the Elswick. A description and drawing of each is given on pp. 67, 68, of the Drill Book.

The action depends upon— Principles of action.

$P$ the pressure between the plates,
$n$ the number of surfaces,
$l$ the length of recoil, and
$f$ the coefficient of friction.

Then $f$ (W + $n$P.) $l$ = the work done.

$$= \text{energy of recoil} = \frac{W V^2}{2g}$$

The disadvantages attaching to all forms of the frictional compressor are that they resist the first movement of recoil, so that the motion begins and ends suddenly, and their action is variable depending upon the state of the surfaces.

In the Bow compressor, if the bars are wedge-shaped, the pressure is liable to alter by the rise of the carriage in firing due to the action of the couple before mentioned.

The advantages of the Bow compressor are that it is simple and powerful, and that the elasticity of the bow form causes an equable pressure to be maintained, even if there are any slight variations in the plates, &c. The disadvantages are, that it has to be re-adjusted each round, and that it is not automatic.

### *Hydraulic.**

In carriages fitted with hydraulic compressors (or buffers) the energy of recoil is employed in doing work:— Work done.

1. In overcoming the resistance due to the friction of the carriage in motion, and to the incline of the slide.

2. In communicating energy of motion to the liquid in the compressor, which energy is quickly transformed into heat.

Since the resistance offered by the hydraulic compressor depends upon the energy of motion communicated to the liquid, its efficiency depends largely upon the area of the orifices through which the liquid must flow.

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* This is taken mainly from an article by M. Canet in the Revue d Artillerie, Vol. XIII., p. 436, to which officers are referred for the mathematical treatment of the question.

Classification of hydraulic compressors.

Hydraulic compressors may therefore be divided into:—

1. Compressors with valves of constant size.
   (*a.*) Valves always open (Service).
   (*b.*) Valves closed by a constant pressure (Krupp, Rendel).
2. Compressors with valves of variable size.
   (*a.*) With inclined sides (Butter).
   (*b.*) With a circular slide valve (Vavasseur).

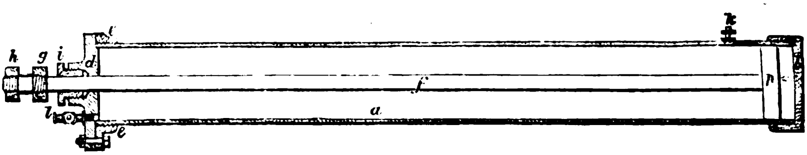
*The Service Buffer.*

Service buffer.

The general description of this is given in the Drill Book, pp. 69, 70, and full details as to the management will be found in the "Instructions for Armourers." The annexed drawing and explanation may be of use—

Cylinder *a*, Fig. 2, of wrought iron or steel.
Cover *d*, of cast iron, with eight bolts.
Flange *e*, „
Cap *b*, „

FIG. 2.




Piston *p*, of wrought iron.
Piston rod *f*, of wrought iron, with collar nut *g*, and connecting nut *h*.
Plug *k*, for filling hole, of wrought iron.
Packing gland *i*, of metal.
Emptying cock *l*, of metal.

Advantages.

Its advantages are: it is simple, it offers no resistance to the first motion of the carriage at the commencement of recoil, and is completely automatic; it requires no attention while running in and out by hand.

Disadvantages.

Its disadvantages are: to compensate for the volume of the piston rod which passes in and out of the cylinder, it is necessary to leave a certain air space, which is a cause of irregularity; it will not hold the carriage when the ship is rolling; it strains the material considerably, since when the carriage has attained its maximum velocity the resistance is considerable, after which it decreases rapidly. This great resistance

considerably increases the couple tending to turn over the carriage of which mention has been made.

Disadvantages of service buffer.

To correct this radical defect, and obtain during recoil either a uniform or progressive resistance, various means have been tried; such as varying the sizes of the holes during recoil, or closing holes of constant size by valves loaded by a weight either constant or variable, which the liquid must pass.

## *Krupp.*

Krupp's hydraulic compressor.

The arrangement of Krupp's hydraulic compressor is not so simple as the buffer in use in the English service, but it possesses the advantages of controlling the gun in a sea-way, and in offering a more uniform resistance to the recoil.

It consists of a cylinder filled with glycerine, attached to the carriage, and of a piston head with valve arrangement secured to the slide by means of one piston rod in front and another in rear. This makes the piston head a fixture over which the cylinder travels.*

The bronze piston head consists of two portions (*a* and *b*) rabbeted together, and secured by four screw through bolts. A cylindrical air space (*c*) is left in the centre. In the front portion of the piston head are four holes, cylindrical in front, coned in rear, which are opened or closed by the valves (*f*) attached to the steel valve plate (*e*) which slides backwards and forwards in the air space. The front of each valve is coned, and fits accurately the coned portion of the hole. To the front of each cone is attached a guide consisting of two cross ribs which slide in the cylindrical portion of the hole. On the back of the cone valve is a projection with a screw at the end, on which fits a countersunk nut, by means of which the valve is attached to the valve plate. Four holes (*g*, *h*) are bored through the valve plate and the rear portion of the piston head through which the liquid escapes when the valves are open.

Leather collars (*ii*) are attached to the front and back of the piston head by means of iron washers and the through bolts, so that it has no play in the cylinder.

The front piston rod has a flat disc (*k*) at its rear end, and in front of it a screw thread (*l*) by which it is screwed into the front portion of the piston head.

The rear piston rod is a tube, and is screwed into the rear

* An improved buffer has been recently produced.

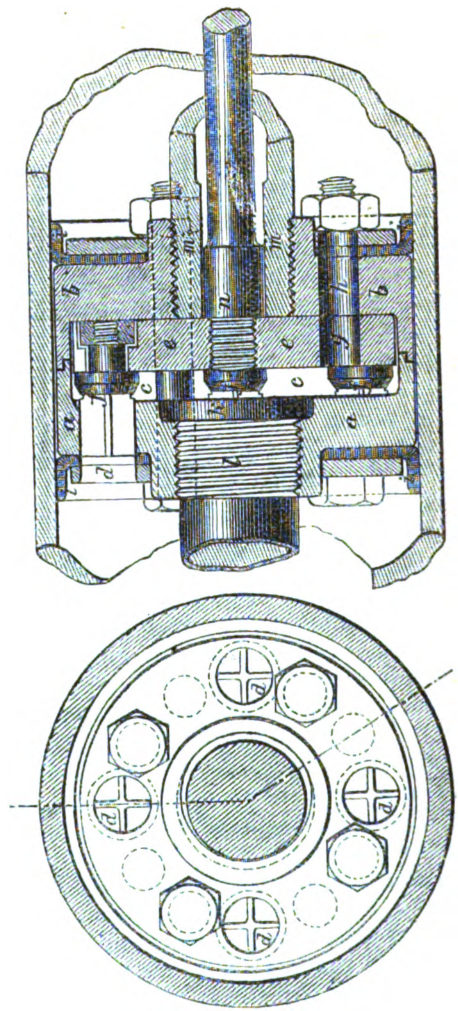
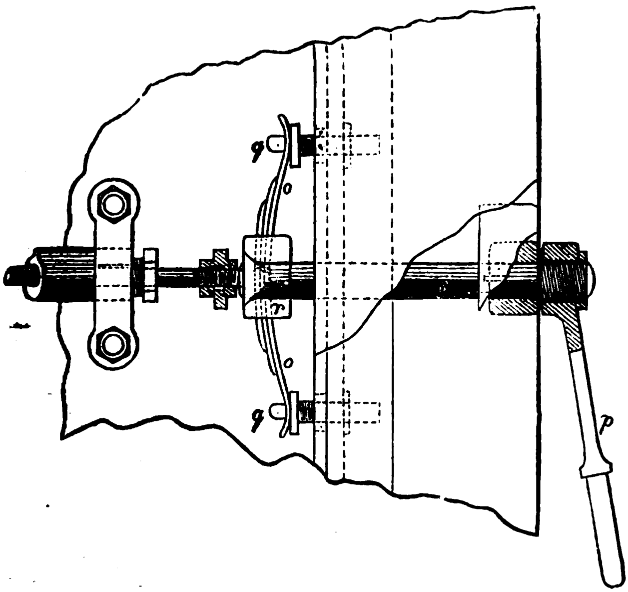


Fig. 3.

portion of the piston head. A valve rod passes up the centre of the rear piston rod, and its front end ($n$) is screwed into the valve plate. The rod works in a packing gland at the back of the piston rod. Its rear extremity is connected, by

Fig. 4.




means of a coupling nut, with the projecting screw on the spring box ($r$). The ends of the spring ($oo$) are slotted and butt against the regulating bolts ($qq$). The shaft ($s$) serves to draw back the spring and the valve rod. It is fixed to the top of the spring and passes through the rear transom, its projecting end being screwed to take the valve lever ($p$). Turning the lever to the right presses back the spring, draws the valve rod to the rear, and thus opens the valves.

**Action.** The action of the buffer is as follows: at the commencement of the recoil the great velocity with which the cylinder (attached to the carriage) moves to the rear exerts so great a pressure on the liquid in front of the piston head that the valves open, and the liquid flows with great rapidity into the portion of the cylinder in rear of the piston head. As the velocity of recoil, and therefore the pressure, diminishes, the valves gradually close by the action of the valve spring, and are completely closed at the termination of the recoil.

The carriage can then move neither backwards nor forwards. To run the gun out the valves are opened by turning the valve

Action.

lever to the right, and as the amount of opening of the valves can be regulated by the lever the gun is well under control.

Should the lever be left so that the valves are open, when the gun is fired, an accident will occur. To obviate this, an arrangement has been fitted by which the valves close automatically as soon as the lever is let go.

### *Butter.**

Butter.

In this compressor the four ordinary holes in the piston are replaced by a semicircular groove at each side of it; these grooves fit over a rib secured along the interior of the buffer cylinder. The clearance between the grooves and ribs furnishes the passage for the return flow of the oil on discharge, and this clearance is made variable, large at first, so that there may be comparatively little opposition to recoil, and gradually decreasing after, that the opposition may increase, by making the ribs tapering. An adjusting arrangement is also added by which the amount of clearance or area of passage can be varied with the charge (or probable violence of recoil), consisting of sliding pieces placed in the piston head, and so fitted that by means of a wedge they can be pushed out to reduce, or drawn in to increase, the area. The wedge is moved as required by a graduated screw in the top of the piston, to get at which it is necessary to bring the latter under the filling hole of the buffer.

### *Vavasseur.*

Vavasseur.

This compressor consists of two pistons fixed on either side of the slide, the first in rear, the second in front, and working in cylinders attached to the carriage. Each piston is fitted with four holes, and on its front face is fitted a circular slide valve, also with four holes.

The pistons are fitted with studs working in spiral grooves in the cylinder, so that in recoil the pistons revolve, gradually closing the holes, since the circular valve does not turn.

A tube joins the two cylinders, so that the fluid displaced by the piston entering its cylinder may pass into that from which the piston is withdrawn. To this tube is attached a valve, which prevents the flow of liquid when required, and thus holds the gun in a seaway.

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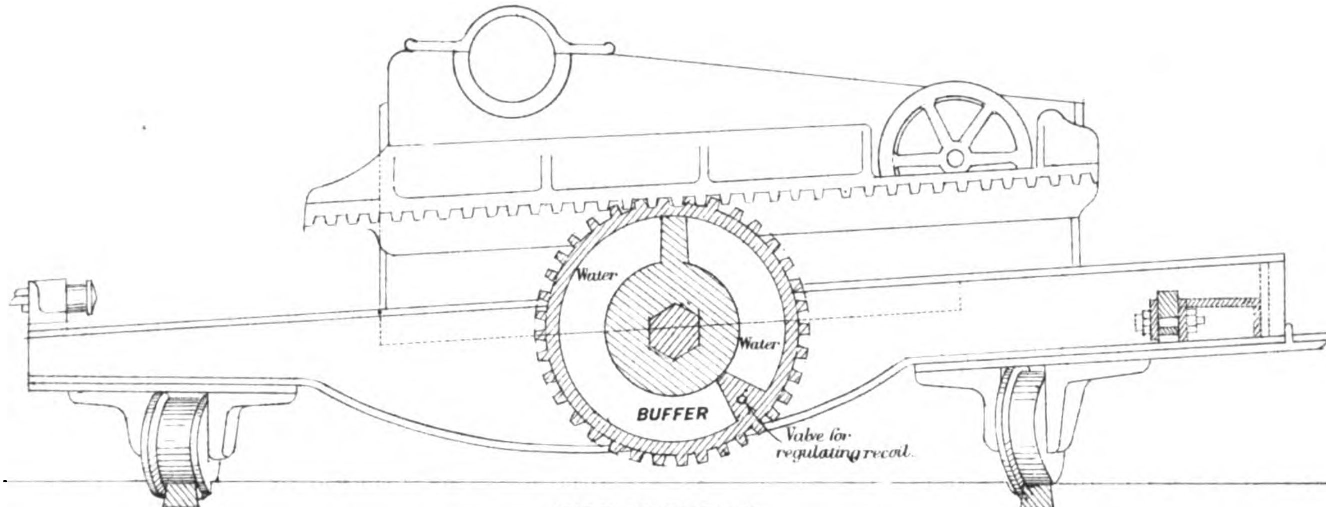
* Journal, R. A. Institution, Vol. IX., p. 340.

SKETCH OF NEW CIRCULAR HYDRAULIC BUFFER,

*as fitted to 38 ton Gun.*




SIDE ELEVATION.

*Front cover of buffer removed to show the action.*

face page 73.

Dangerfield Lith. 22 Bedford St Covent Garden

The action of this buffer relatively to those of other descriptions is shown by the diagram, p. 74. Vavasseur.

This compressor is now under trial by the French navy, and the experiments so far carried out have been so successful that it is being fitted to a 24 c.m. carriage and slide.

## *Circular Buffer.*

The arrangement of the circular buffer is shown in the annexed diagram, which shows the buffer with the front cover removed. It consists of a cylinder working on a fixed gudgeon, which has a projecting wing fitting the cylinder internally, while a similar wing, or partition, is fixed to the cylinder, one of these wings is provided with a hole for the passage of the fluid, while the other fits the cylinder and is quite solid. As the cylinder is driven round the fluid is forced from one part to the other through the small hole, which is enlarged or closed by a valve worked and set at pleasure from the outside. Around the periphery of the cylinder is a series of strong steel teeth, and a steel rack with similar teeth is fixed to the brackets of the carriage; on recoil the rack drives the cylinder round with more or less velocity, the resistance to the free flow of the fluid absorbs the recoil precisely the same as is the case with the common buffer. Circular buffer.

The advantages of this buffer are that the resistance can be adjusted to any change of charge; with the present carriages it can also be placed more nearly in line with the axis of the gun than the common buffer. Advantages.

The disadvantages are that motion is communicated to the buffer by means of toothed gear, and the buffer itself will not hold the gun in a seaway. Disadvantages.

It also possesses the radical defect that the resistance rises to a high maximum, and then decreases rapidly.

The following were the resistances when fitted to a 38-ton gun, and fired with a 160 lb. charge and an 800 lb. projectile :—

| Recoil in inches. | Pressure in lbs. |
|---|---|
| 15 | 75,749. |
| 30 | 53,568. |
| 45 | 30,551. |
| 60 | 13,811. |

Explanation of diagram.

The great difference in the action of the various hydraulic buffers is indicated in the annexed diagram, which shows the resistance determined from theoretical considerations.

Line 1 represents pressures with air space, calculated from 0 to 5·2 feet recoil, at which point the air passes through the piston and recoil is stopped by friction only at 5·75 feet.

Line 1*a*—pressures, supposing that from 2 feet recoil the pressure is the same as in a full cylinder without air. This gives a recoil of 5·95 feet.

Line 2—pressures in full cylinder without air, 5·75 feet recoil.

Line 3—uniform pressure throughout, recoil 5·75 feet.

Line 4—regulated pressures, with varying holes.

Line 5—variation in volume of air-space corresponding to pressures line 1.

The regulated pressure, line 4, is obtained from two orifices in piston of form D, fig. 2, closed by valve rotated uniformly during recoil by projections E in rifle grooves in cylinder. The orifices are closed by the edge F of opening in valve gradually moving over them in the direction shown by the arrow. The two orifices G remain uncovered.

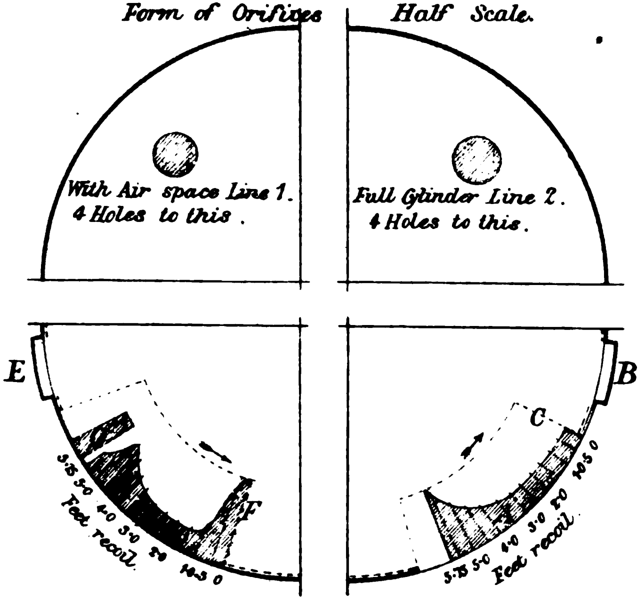
The uniform pressure throughout, line 3, is obtained from two orifices in piston of form A, fig. 2, closed by a valve rotated uniformly during recoil by projections B in rifle grooves in cylinder. The orifices are closed as above.

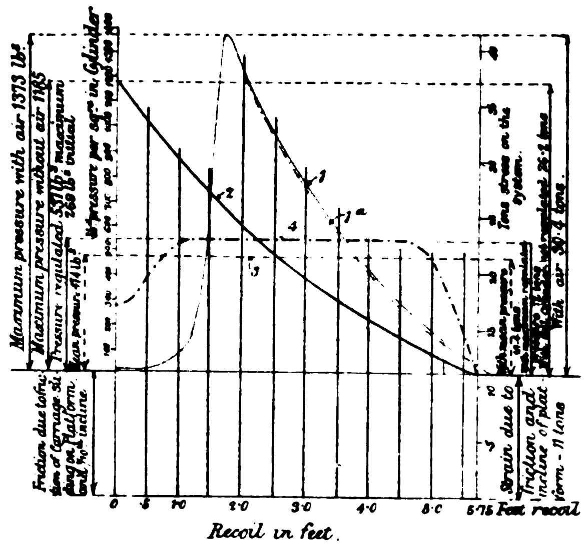
The calculations are made from the following data:—

Weight of system, W = 98448 lbs.
Initial and maximum velocity of recoil, V = 13·45 ft.
Resistance due to friction and incline, 4° = W × ·25.
Volume of air in cylinder = 0·44675 cub. ft.
Area of holes in piston = 1·327 sq. inch. × coef. of contraction, ·95.
Inside diameter of cylinder, 8″·05.
Liquid in cylinder oil, pressure on sq. in. per foot in height, = 0·4 lb.

It is to be specially remarked that these results are not strictly accurate, because the initial and maximum velocities of recoil are not identical in practice. The general results are, however, sufficient to show the main differences between the various arrangements.

DIAGRAM SHOWING PRESSURES DEVELOPED IN SERVICE AND OTHER HYDRAULIC BUFFERS FOR THE 12"·5 GUN AS CALCULATED BY MR. E. DONN.

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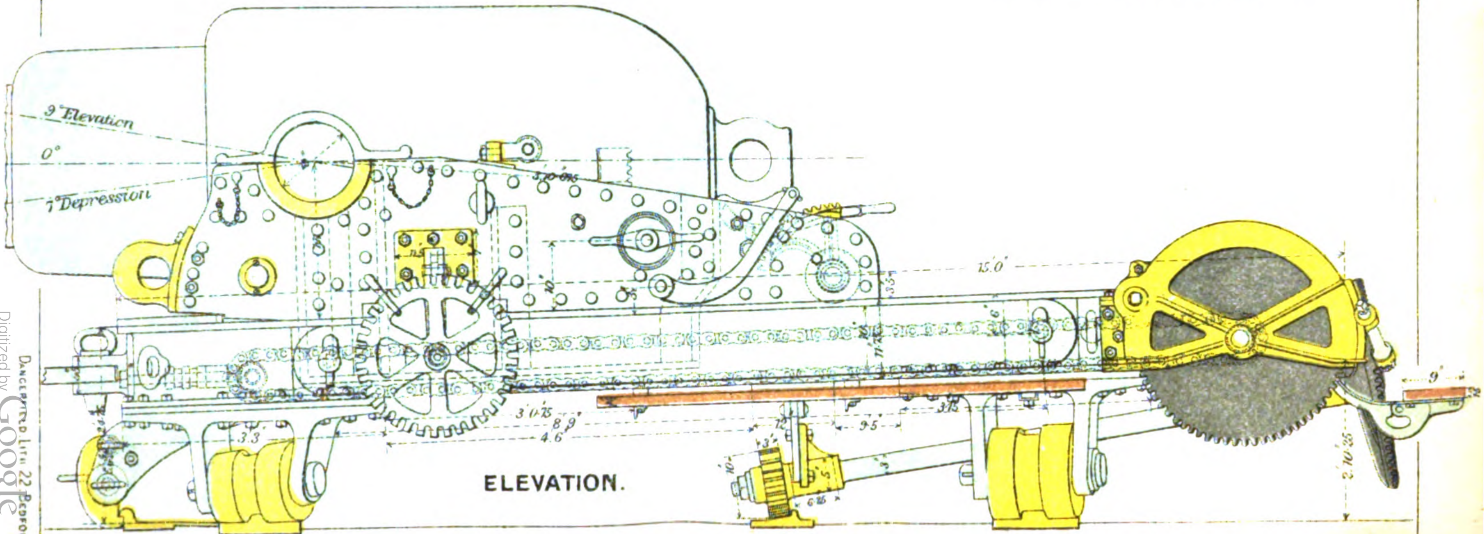
# CAPTAIN SCOTT'S NAVAL CARRIAGE & SLIDE FOR 10 IN. GUNS OF 18 TONS.

## "SULTAN" PATTERN.

Scale.

Inches 12 9 6 3 0 1 2 3 4 5 Feet.

| | Weight. | Tonnage. |
|---|---|---|
| Carriage | 80 Cwt. | 3·785 tons. |
| Slide | 122 „ | 13·65 „ |




ELEVATION.

To face page 75.

## Systems of Mounting.

### *Broadside Scott.*

This is due to Captain R. A. E. Scott, R.N., and has been adopted for all naval broadside carriages for 10″ guns and above, and for some 9″ guns. **Scott.**

As will be seen from the opposite diagram the distinguishing feature of this mounting is a long, low carriage mounted on a high slide. This secures the usual height of axis above the deck, and at the same time reduces the tendency to jump by diminishing the height between the axis of the gun and the compressor (the arm of the couple).

The carriage is of the box girder or double plate description, the sides being connected by transoms and bottom plate. **Carriage.**

The slide is of wrought iron, the sides of the usual **I** form to support the weight of the gun and resist the downward blow on firing. These sides are bent round in front, so as to meet, and are further connected by transoms and bottom plates. **Slide.**

The slide travels on permanent rollers, grooved so as to fit over the rib with which the racer is provided. The object of this was to transmit part of the recoil to the racers instead of trusting entirely to the pivot to which the slide is connected by the pivot bar. In practice, however, it is found that this can not be done, as any elongation of the pivot bars increases so largely the friction between the rollers and ribs of racers that the gun cannot be trained.

The elevating gear is of the usual service "capstan head" form, and possesses the following disadvantages:— **Elevating gea[r].**

1. The gun cannot be elevated up to the instant of firing.
2. Four men are required to work it.
3. It is liable to run down, the clamp nipping the drum at the centre, where it has little hold, instead of at the circumference.

When the gun is fired the carriage itself rests on the slide, so that a large surface is in contact to receive the blow. When **Running in and out gear.**

*[Ru]n and out [g]ear.* required to run in or out by hand, it is necessary to place the carriage on rollers to reduce the friction. This is done as follows:—The fore part of the carriage is fitted with rollers so arranged that they come into action when the rear part is raised, but are not in contact when it is lowered. The rear of the carriage is fitted on each side with rollers with eccentric axles, by which they can be thrown in or out of action as required. The eccentric is worked either by an hydraulic jack or by a cog wheel, drum, and lever.

This canting the carriage to throw the rollers in and out of action is objectionable, because—

1. Time is lost.
2. There is a liability of the gun being left on the rollers, on firing.

There seems to be no reason why the carriage should not be kept permanently on the rollers, the number being increased to distribute the blow. The control of the gun is simply a matter of efficient brake power.

The gear used for running in and out consists of two endless chains running round a sprocket wheel at each end of the slide. The one at the fore end can be adjusted so as to tauten the chain, while the other is attached to a shaft driven by spur wheels and pinions worked by winch handles. The chain can be made to take the teeth of a sprocket plate which is fitted to the carriage. The arrangement for doing this is somewhat similar to the annexed sketch which is that for a 9″ carriage.

The gear consists of the following parts, viz.:—

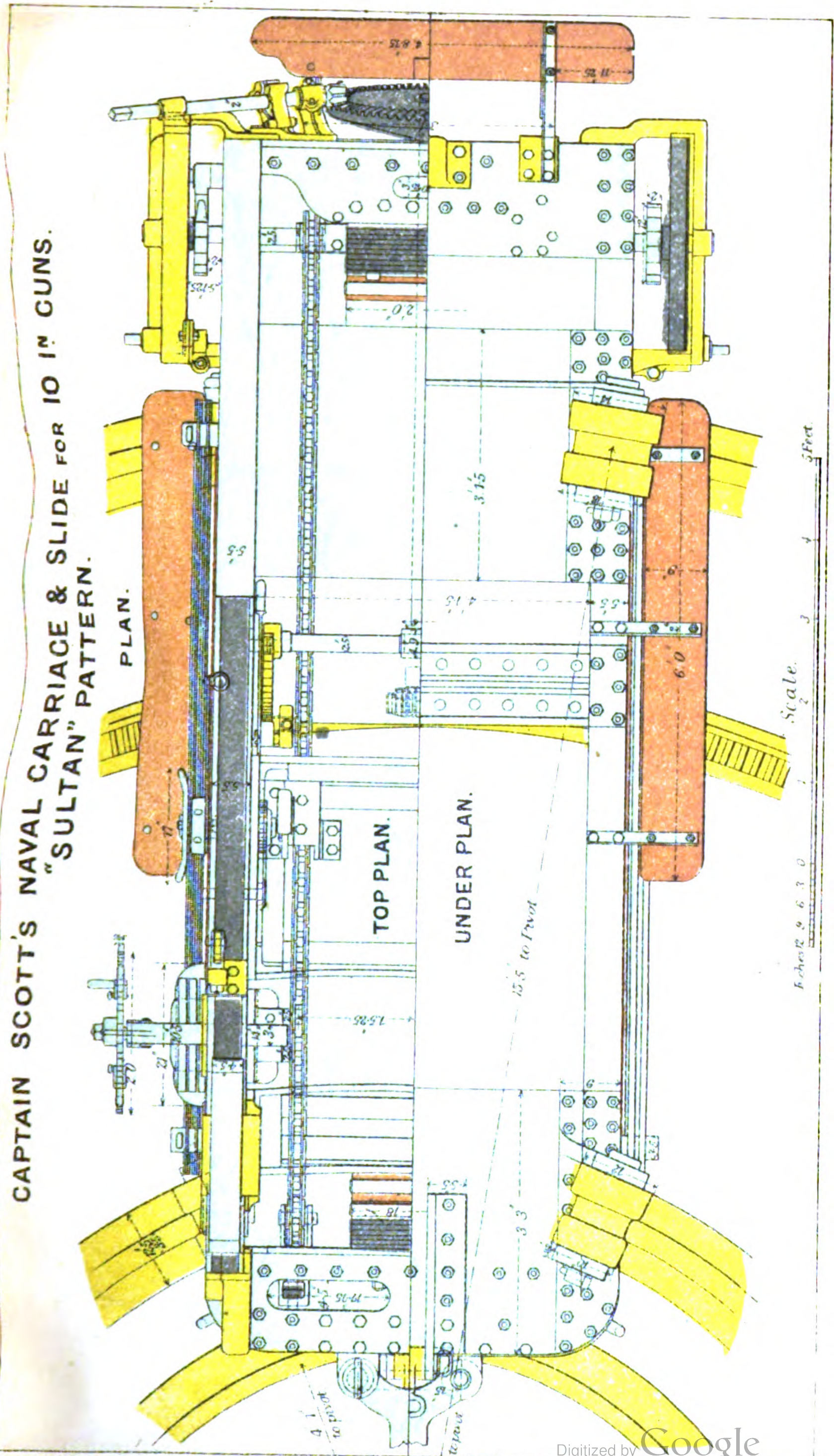
A movable iron block C, held by two bolts *c*, *c*, passing through elongated holes in it, between two small brackets E, E, bolted beneath the bottom plate to the left rear of the carriage.

A link A, attached to the block by a bolt D, with keep pin, the bolt passing through elongated holes in the brackets of the block.

An eccentric B, which works in the top of the link, and is secured in it by a screw *b*; the shaft H passes through a metal bearing in the left side of the carriage, and has a bent lever K, by which it is worked, secured upon its outer end by a keep pin.

A stirrup F, attached to the rear of the block by screws.

CAPTAIN SCOTT'S NAVAL CARRIAGE & SLIDE FOR 10 IN. GUNS.
"SULTAN" PATTERN.

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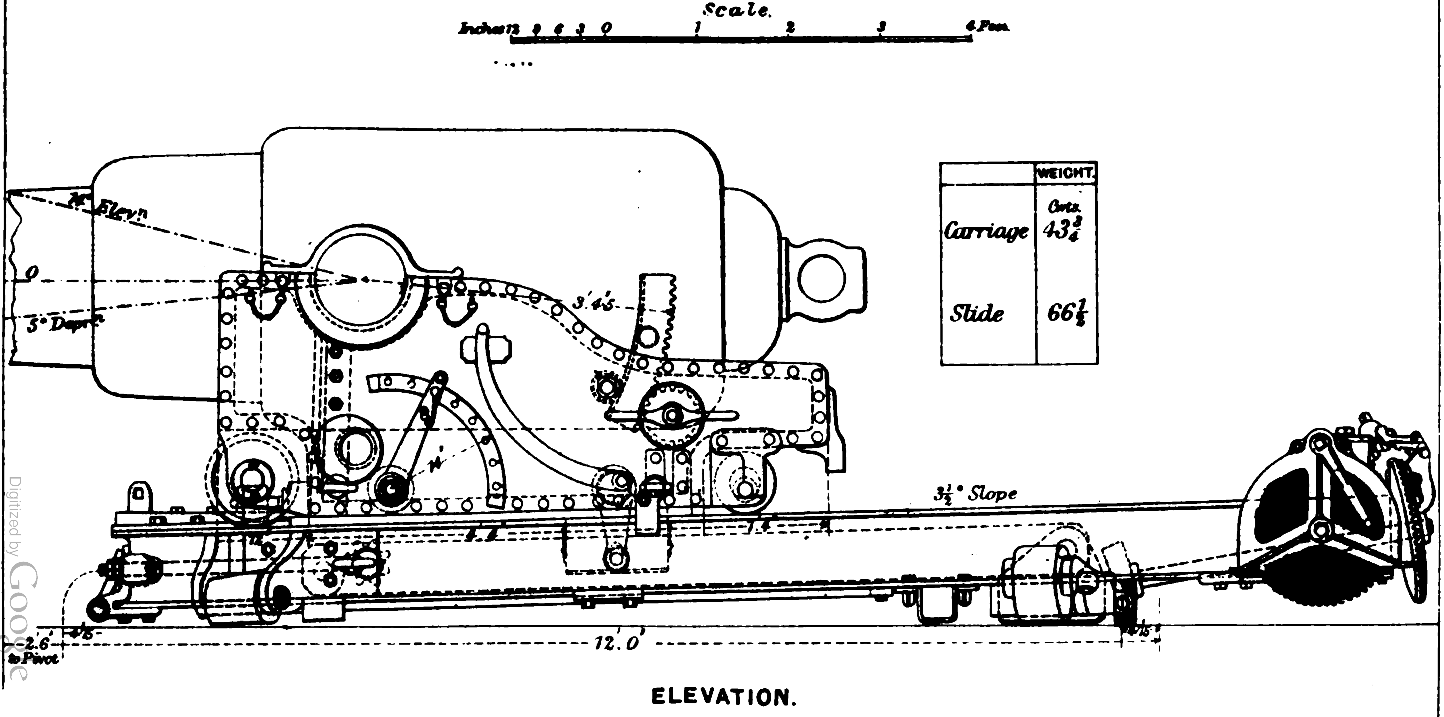
Dangerfield Lith 22, Bedford St Covent Garden

# DOUBLE PLATE W. I. CARRIAGE & SLIDE FOR 9 IN. GUN.



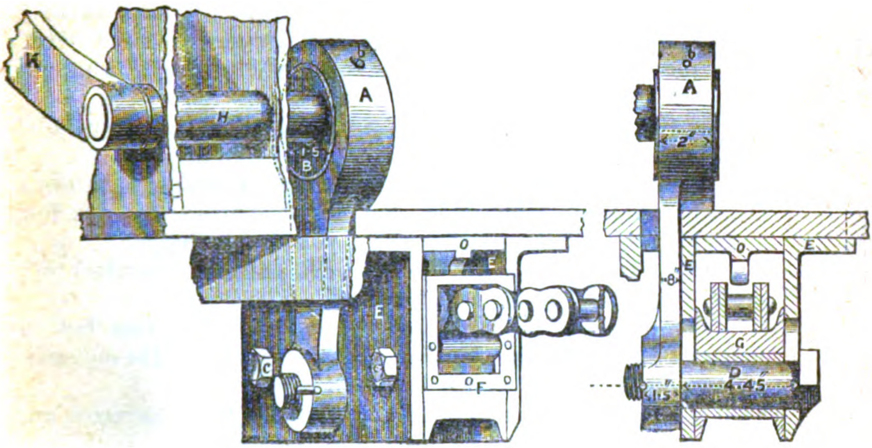

| | WEIGHT. |
|---|---|
| | Cwts. |
| Carriage | $43\frac{3}{4}$ |
| Slide | $66\frac{1}{2}$ |

To face page 77.

Dangerfield Lith. 22 Bedford St. Covent Garden

A sprocket plate O, attached to the bottom of the carriage between the brackets of the block.

FIG. 5.




Training gear.

The arrangement for training consists of a toothed metal rack in the deck, into which gears a pinion driven by a shaft; on the rear end of this there is a crown wheel into which gears a bevel pinion on each side, worked by a winch handle. The arrangements for controlling the gear are a brake on the training gear, and on the later patterns two brakes on the rib of the racers.

Compressor.

The arrangement for controlling the recoil consists of the bow compressor of which a drawing will be found in the Drill Book, p. 67, and mention is made of it at p. 67 of this work.

An hydraulic buffer is also fitted in some cases, see p. 68.

## *Broadside Service.*

Double plate carriage.

The distinctive feature of this mounting is a high carriage and low slide; see diagram opposite. It will be observed that the distance from the axis of the gun to the compressor is considerable, and therefore the tendency to jump especially with high charges is very great. It is distinctly inferior in principle to the Scott carriage, and is only in use for carriages up to the 9-in.

The elevating and running in and out and training gear generally similar in principle to that in use for the Scott carriage. The chief differences are—

Differences. The slide is not on permanent rollers, the rear ones being fitted with eccentric axles worked by levers by which the rollers can be thrown in and out of gear. This arrangement is defective, because the gun cannot be fired whilst on the move, which is all important when firing at a moving object.

In the heavier natures it is also very difficult to train when the gun is in.

The racers are not ribbed, which, as affording a means of applying an efficient brake, and of preventing the gun from fetching way if the pivot bars go, is a disadvantage.

The compressor is of the Elswick pattern described in p. 68 of the Drill Book, see also p. 66.

The carriages used for light guns are single plate, but are otherwise very similar to that described above. The mounting for a 20-pr. gun is shown in the diagram, p. 79.

Modifications are now being made in these carriages and slides to enable them to withstand the increased strains produced by firing heavy charges.

## *Turret Hand-worked.*

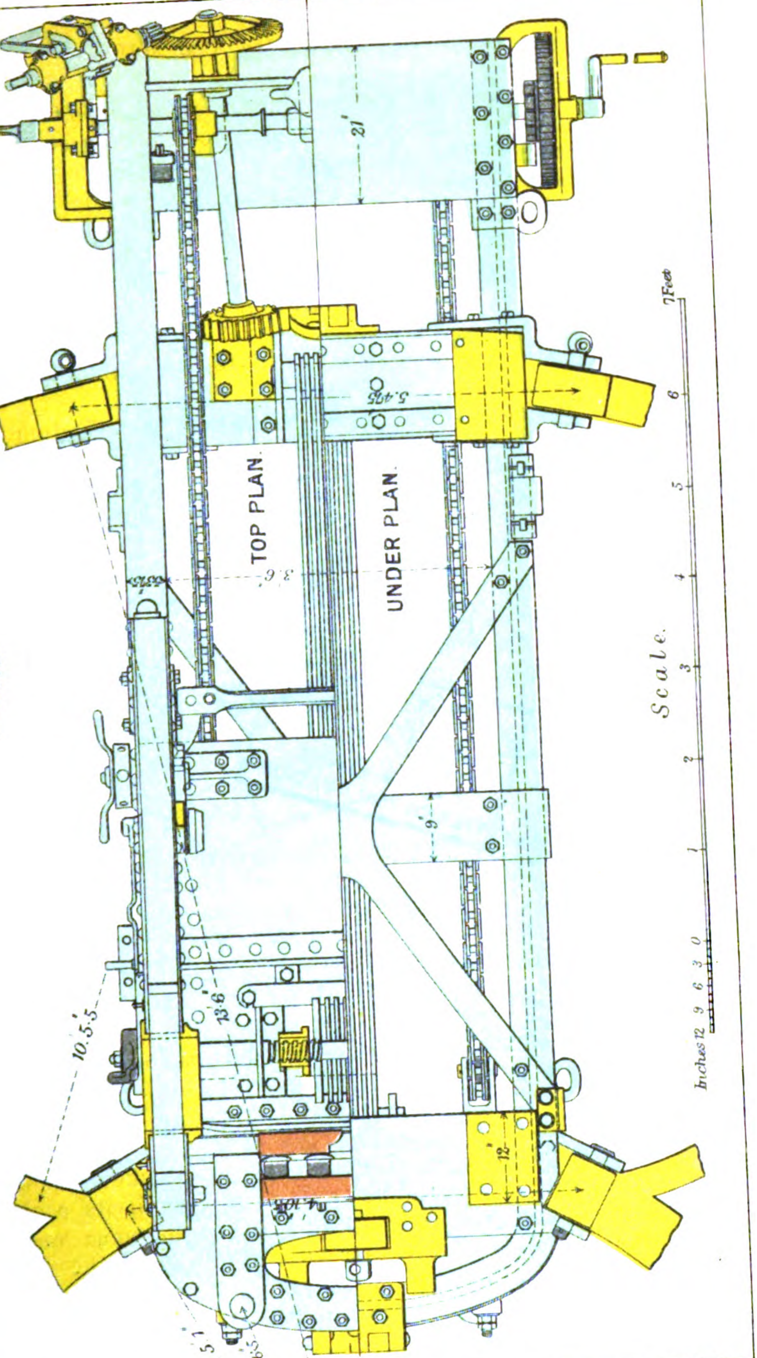
Slides. The slides for turret carriages are fixtures built into the turret; the sides are formed of two upright plates with a piece of tee iron riveted between them at top, the flange of which forms the bearing surface of the carriage, and at the bottom they are connected to the deck by angle iron.

The training is effected by the revolution of the turret itself.

Carriages. The only essential point in which turret differ from broadside carriages, is in their possessing compound vertical pivoting gear to minimise the vertical area of the port. This is effected by supporting the gun in wrought-iron blocks, susceptible of vertical motion in the brackets. These blocks are united by a "saddle" acted on beneath its centre by the ram of an hydraulic jack, attached in some cases to the bottom plate of the carriage, in others to the floor of the turret. Iron blocks of different lengths are used to support the trunnion blocks in the different position in which it is intended to fire.

DOUBLE PLATE W. I. CARRIAGE & SLIDE FOR 9 IN. GUN.

PLAN.

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DANGERFIELD, LITH. 22. BEDFORD ST. COVENT GARDEN

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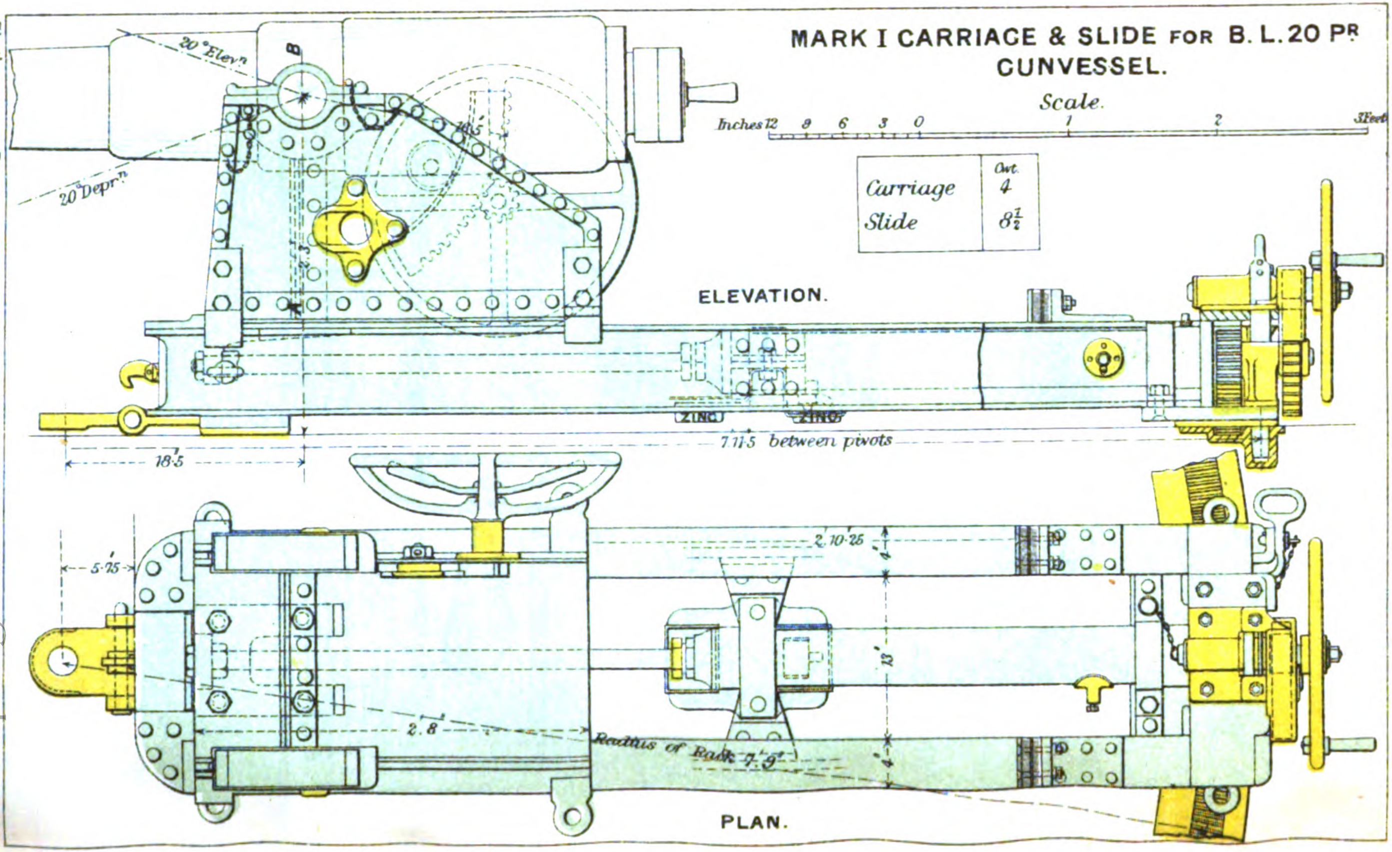



MARK I CARRIAGE & SLIDE FOR B. L. 20 PR. GUNVESSEL.

| | Cwt. |
|---|---|
| Carriage | 4 |
| Slide | $8\frac{1}{2}$ |

Dangerfield Lith. 22 Bedford St. Covent Garden.

In order to admit of a sufficient number of men being employed the running in and out gear (Scott's) is worked by several winch handles outside the turret, while by means of a clutch the shaft of the gear of one slide may be connected with that of the other, so that if necessary the winch handles at both sides of the turret (*i.e.* of both slides) may be applied to run back the same carriage. **In and out gear.**

The elevating gear consists of a train of gearing attached to the cascable of the gun. It can be worked by one man, and is adapted for use with the axis of the gun at different heights. Its defect is that the man attending it has to climb on to the slide to work it, so that the gun cannot be elevated up to the instant of firing. **Elevating gear.**

The recoil brakes consist of the bow compressor and hydraulic buffers. **Compressors.**

*Turret Hydraulic.*

The largest gun which can be worked by hand in the turrets of the Thunderer is the 35-ton, but with the hydraulic gear 38-ton guns can be mounted. **Advantages.**

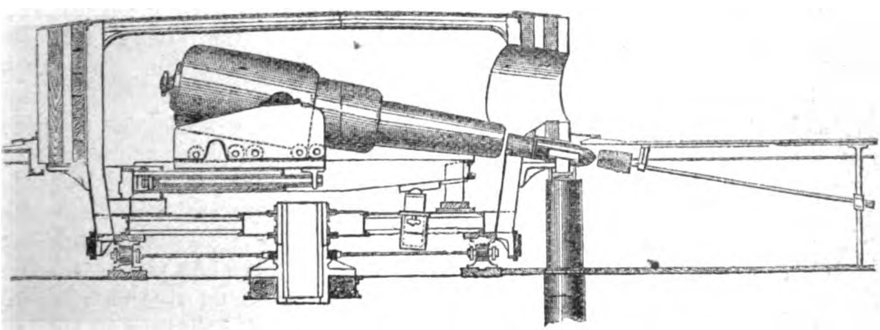
This is the first advantage of the system, the others are :—

Guns of the heaviest weight can be worked as rapidly as those of moderate dimensions.

Fewer men are required.

The arrangement fitted in H.M.S. Thunderer is shown in Fig. 6.*

FIG. 6.



There are two distinct features in this system :—

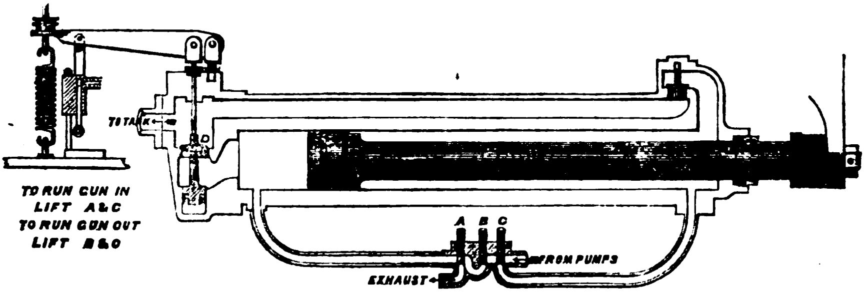
1. The running in and out arrangement, which also controls the recoil.
2. The loading arrangement.

* Rendel on Gun Carriages, 1874.

Running in and out.

The first is explained by reference to Fig. 7, which represents the cylinder or press, to which the pressure is transmitted from the engine by means of water through a *small* pipe.

FIG. 7.




HYDRAULIC RECOIL PRESS.

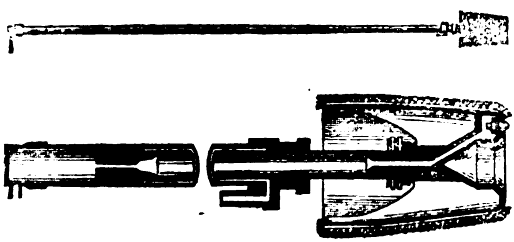
The gun on recoil drives back the piston and is arrested by the resistance which the valve (D) offers to the escape of the water from the cylinder. The valve is loaded with a spring, which may be adjusted to give any required resistance, and so meet the variations of the force of recoil. It is also partly balanced, to lessen the load required upon it. The area of the piston rod is one half that of the piston, and the gun is run out by admitting the water pressure to both sides at once. For running the gun in, the pressure is admitted to the front of the piston only, the exhaust being at the same time opened to the rear. Clack valves in connexion with a waste-water tank are used to insure the cylinder being always full, and there is a relief valve on the front for preventing any excessive strain. On the rear the recoil valve acts as a relief valve upon occasion. It will happen in some cases that the pressure required on the valve (D) to arrest recoil falls short of that necessary for running the gun in or out, in which case the water admitted to the cylinder for the purpose would lift the valve and escape to waste. This is provided for by making the act of opening the cylinder-inlet valve (A) place an additional load on the recoil valve (D), retaining it there so long as the inlet valve remains open. Fig. (7) shows one method of placing the extra load on the recoil valve, viz. by a small inverted press, having in its normal condition an open communication with the waste-water tank, which communication is closed, and the press charged with water under pressure, by the first movement of the lever employed to open the inlet valve (A) of the recoil cylinder.

The loading is effected by training the turret so as to bring the muzzle of the gun opposite a set of loading gear in the turret room, and then locking it in that position. The gun, being on the middle step, is at the same time depressed, so that the charge may be raised to the muzzle, and pushed home from below the upper deck by the hydraulic rammer. Loading.

The projectile is brought up to the loading place on a small truck controlled by a friction plate which clamps it to the rails whenever the truck handle is lowered. It is then run on to a hoist which rises with it out of the main deck until arrested by stops placed so as to bring the hoist to rest when the projectile is in line with the bore of the gun. The charge having been first pushed home, the projectile is rammed home by the same hydraulic rammer, which is telescopic, and consists of a parallel tube in which runs a piston rod armed with a sponge head.

The sponging is carried out with the same rammer, which is fitted with a valve, which opens when pushed against the bottom of the bore, to allow a stream of water under pressure to wash out the gun. The arrangement is shown in Fig. 8. Sponging.

FIG. 8.



HYDRAULIC TUBE RAMMER.

The gun is made partial muzzle pivoting by hinging the slide horizontally at the rear, the front end being free to be raised or lowered by a hydraulic ram, but placed for firing on chocks suitable to the different heights required. Muzzle pivoting.

It will be observed that in the arrangement just described the hydraulic system is applied to a gun mounted on a carriage of the ordinary form. As the use of steam power makes the friction of no moment, the use of rollers may be dispensed with, and hence the long, high carriage, necessary to contain them is also not required. This has led to the adoption of the arrangement shown in Fig. (9), in which the trunnions Improved turret mounting.

Improved turret mounting.

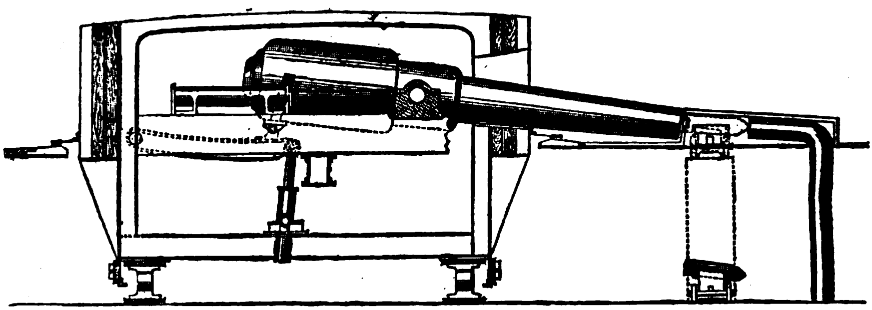
are simply fitted into blocks sliding on the slide. The recoil press is placed in line with the trunnions, so that the tendency to jump is entirely removed.

Another feature of this system is the elevating arrangement, which consists of a beam hinged in rear to the slide or wall of turret, the other end being actuated by an hydraulic lift. The breech slides along this beam. It is most important with this arrangement that if the gun has preponderance, provision should be made to meet the strain which the tendency to rotate before alluded to will throw on the elevating gear.

The advantages of this system are that:

1. The gun can be elevated up to the instant of firing.
2. The gun always recoils into the same vertical position.
3. It is easy to fit an arrangement by which the capain of the turret can himself lay the gun and at the same time adjust the sight.

Fig. 9.



It will also be observed that the telescopic rammer is replaced by a jointed one. This is used to save space.

The hydraulic system can also be applied to working breechloaders, in which case a heavy breech-piece can be handled with ease, so that its weight becomes of less importance. This might lead to further simplicity in the breech mechanism, and to an increase in the rapidity of the fire.

Barbette.

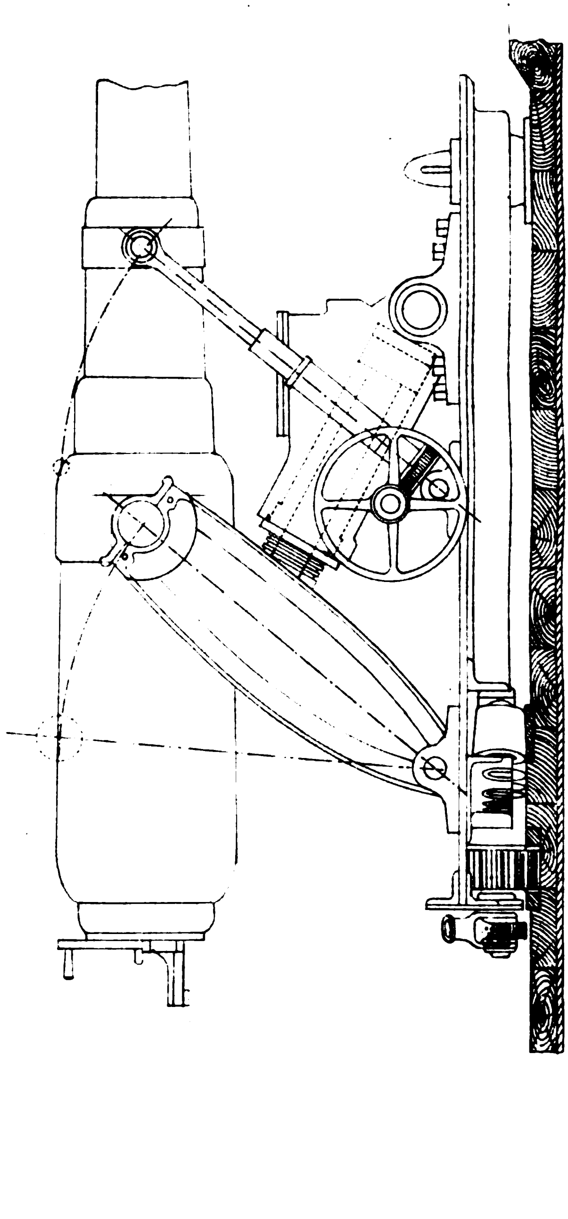
The hydraulic system has also been applied to guns mounted en barbette on the disappearing principle. The recoil press and loading arrangement are essentially the same in principle as those described for turrets.

## *Krupp's Half Slide.*

Half slide.

This arrangement being different to any in use in the English service is worthy of attention.

ALBINI CARRIAGE FOR 6 INCH GUN.



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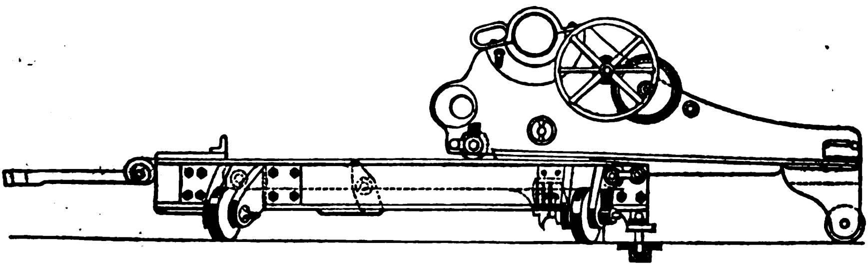
DANGERFIELD LITH. 22, BEDFORD ST. COVENT GARDEN

The carriage brackets are low, and are connected by the bottom plate and front transom. The upper part of the carriage is not horizontal as in the English carriages, but sloped to the front to diminish the strain on the capsquares. **Half slide.**

The slide is so constructed that the rear of the carriage runs off it after a short recoil, and is then supported on the deck by a roller. There are, therefore, no rear rollers, but the front rollers are fitted with eccentrics and lever sockets. Bearing down the levers to the rear raises the carriage on to its front rollers. The deck roller is a hollow bronze cylinder, somewhat

FIG. 10.



thicker in the middle than at the ends, and the axle of which is carried by two brackets screwed under the bottom plate of the carriage. The roller does not touch the deck when the gun is run out but only after it has recoiled a certain distance. The rear end of the slide slopes slightly to the rear. There are eye bolts for side tackles near the rear of the brackets and a third eye bolt for running in tackle at the rear of the bottom plate between the brackets. The carriage is fitted with a pair of clip plates in front, and immediately behind them a pair of long guide irons. The former are fitted with projections corresponding to the rear stops of the slide.

The advantages of this mounting are that space is economised. **Advantages and disadvantages.**

The disadvantage is that the gun cannot be trained for loading and this system is therefore only suited for B.L. guns. Difficulty may also possibly be experienced in running out.

## *Albini.*

The arrangement of this method of mounting, which was proposed by Captain Albini and designed at Elswick, is shown by the annexed diagram. This carriage is suited for a B.L. gun of moderate size, and possesses several advantages. **Albini.**

Albini.

The gun is easily worked, as its weight causes it to return to the firing position after discharge, and the elevating gear can be attended up to the instant of firing. The mounting is also very compact.

The disadvantages are that a great strain is brought upon the front pivot and upon the deck.

It will be observed that the recoil is taken up by an hydraulic buffer, which belongs to the first class, with holes of constant size closed by a constant pressure.

## *Non-Recoil.*

Krupp, non-recoil, armoured gun.

The only two guns which have hitherto been mounted on a non-recoil carriage are the Krupp, 15·5 c. m. and 8·7 c. m. guns.

The armoured, muzzle pivoting, non-recoil 15·5 c. m. Krupp gun may be briefly described as follows :—

The gun fires through a small port, completely closed by a sphere screwed on to the muzzle of the gun. This sphere works in a cavity in the inner part of the port, a ball and socket joint being thus formed. The gun is consequently pivoted, both for elevation and direction, on its muzzle only. The sphere can be unscrewed and the gun removed, restored to its place, or replaced by another. The carriage consists essentially of two nearly upright guides for the trunnions to work in, in the lower part of which are the cogged wheels of the elevating and training mechanism, and the rollers on which the gun runs when trained. The number who aims and fires sits on a saddle provided with stirrups on the chase of the gun, and aims through a small hole.

In the course of the Meppen experiments in August 1879, 35 rounds were fired with charges of 14·33 lbs. of prismatic powder, and projectiles weighing 77 lbs. The gun was perfectly steady when fired, the absence of all apparent shock or jar being complete, and on the conclusion of the practice all the parts were in perfect working order.

Light non-recoil gun.

The 8·7 c. m. non-recoil gun is mounted on quite a different principle. The leading features of the mounting may be thus described :—

The trunnions rest in two stout wrought-iron brackets fixed to a wrought-iron axis or pivot which moves above in a circular ring, and beneath on a cylindrical trunnion. As the pivot works tightly in the ring the recoil is absorbed through the trunnion by the brackets, pivot, and foundation.

The elevation is effected by a cogged wheel; the horizontal traversing by moving the gun on its pivot, which turns easily in the ring. A compressor fixes the gun both in a vertical and horizontal position. Light non-recoil gun.

The dimensions of the gun are as follows:—

| | |
|---|---|
| Calibre - - - - | 3·42 in. |
| Diameter of chamber - - - | 5·9 in. |
| Total length - - - | 14 ft. 3¼ ins. |
| Length of bore - - - | 47 cal. nearly. |
| Weight - - - - | 24¾ cwt. |

The gun was fired with a charge of 7·7 lbs. of coarse grained powder and a common shell weighing 22 lbs., which gave the following results:—

| | |
|---|---|
| Muzzle velocity - - - | 1829 f.s. |
| Total energy - - - - | 511.5 ft. tons. |
| Energy per in. of circumference - | 47·5 „ |
| Pressure - - - - | 11·6 „ |

These examples show that guns can be mounted without recoil, and it becomes important to ascertain whether larger guns can be mounted on this principle. Some light may be thrown on this point by referring to the dimensions and performances of the 8·7 c. m. gun. Conclusion.

The first point to notice is the weight, which is nearly double that of an ordinary gun of that calibre. This was the first means adopted to reduce the shock on the fastenings. It is important to remark that this additional weight was usefully employed in adding to the length of the bore.

The second point is the moderate pressure of 11·6 tons. A consideration of this point, combined with the knowledge that improvements in the manufacture of powder will enable this pressure to be reduced, lead to the belief that larger guns may be fired without recoil. The advantages of non-recoil are increased simplicity in the mounting and working, and probably increased rapidity in loading due to the introduction of mechanical arrangements.

For naval purposes, the increased weight necessary to absorb the shock without recoil is of considerable importance and must be put against the advantages gained by working the gun when mounted on this system.

# CHAPTER IV.

## POWDER.

Gun and steam engine compared.

A gun is a particular form of heat engine, and from this point of view differs from the ordinary steam engine principally in the fact that the gas produced by combustion is used as the motive agent instead of the steam gas from water.

In either case the work done is due to the combustion. With the steam engine, the combination of the carbon of the fuel with the oxygen of the air generates heat, which converts the water into steam, by the expansion of which the piston is moved and work is done. With the gun, the carbon and oxygen are intimately mixed together in the powder, and, on firing, their chemical combination produces a large amount of liquid residue and gas at high temperature. The latter expanding does work by moving the shot, &c. The former acts as a source of heat from which the gas is supplied as it expands.

In order to fully understand the action of gunpowder when fired, it is necessary to consider briefly its composition and mode of preparation.

### Outline of Manufacture.

Outline of manufacture.

The materials used are—

Charcoal (C), to supply the carbon or fuel;

Saltpetre or nitre ($KNO_3$), to furnish the oxygen required for the oxidation of the carbon;

Sulphur (S), to accelerate the combustion.

The proportions of these ingredients vary in different countries, those used in the British government factories are approximately as follows:—

Saltpetre 75 parts, sulphur 10 parts, charcoal 15 parts.

The first stage in the manufacture is the purification of the materials. This is most important, as upon it depends the regularity of the action, the keeping qualities, and the safety. Full details will be found in "A Handbook of the Manufacture of Powder," by Captain F. M. Smith, R.A., p. 10.

The next operation is to so thoroughly mix the materials that on the application of heat combustion shall be uniform. This mixing is effected—1. By placing the ingredients in proper proportion in a vessel and then stirring them all up together. 2. By subjecting this mixture to a grinding process in huge mortars, called incorporating mills. The result is an intimate mechanical mixture in the form of cake, something like broken oil cake.

Outline of manufacture.

This mill cake is the real powder, but the pieces are irregular in size, varying from dust to comparatively large pieces of cake; the density is also not uniform. Both of these causes would lead to irregularity in the action.

To obviate this, it is broken up into small pieces, and then pressed uniformly in a machine by hydraulic pressure. After pressing, the powder is in the form of slabs of uniform density, and its after treatment depends upon the description of powder required. Up to this point the manufacture of all grain and cubical powders may be considered as practically the same, the only differences being variations in the quality of the charcoal, in the time occupied in incorporating, or in the density.

If the powder required is a grain powder, such as R. L. G., the press cake is broken up in a machine and the products sifted, so that uniformity in the size of grain can be obtained; but if a pebble powder is wanted, the cake is cut up in a different machine to pieces of the proper size. The remaining operations are of little importance so far as a right understanding of the action is concerned. It is right, however, to mention the glazing, which is carried out to enable the powder to stand transport, &c., and consists in running the powder for a short time in a sort of churn with a certain proportion of blacklead. This rounds off the corners, and gives the hard smooth surface required.

## Action in Closed Vessels.

Little was known in England on this subject previous to the experiments of Captain A. Noble and Professor Abel. Officers wishing to thoroughly understand the recent development of artillery should study their works entitled "Researches on Explosives," "Fired Gunpowder," of which the first part was communicated to the Royal Society in 1875, and the second part in 1879.

Noble and Abel.

Noble and Abel.

The method of experimenting employed was briefly as follows:—

A steel vessel was constructed of sufficient strength to confine the gases on explosion, and charges of powder were fired varying in weight from $\frac{1}{10}$ to $\frac{10}{10}$ of the weight of water which the vessel would hold. This enabled a law to be established between the density and tension of the gas.

Each description of powder used was analysed before being fired, and in the case of the English powders the proportion of the different ingredients was found to be very nearly as follows:—

| | |
|---|---|
| Saltpetre - - - - | 75 |
| Sulphur - - - - - | 10 |
| Charcoal - - - - - | 14 |
| Water - - - - - | 1 |

The charcoal differed considerably in the different powders. For the P. powder its composition was—

| | |
|---|---|
| Carbon - - - - | 85·26 |
| Hydrogen - - - | 2·98 |
| Oxygen - - - | 10·16 |
| Ash - - - | 1·60 |

Gaseous products.

After firing the gaseous products were collected and analysed. The per-centage composition by volume for P. powder was found to be—

| | | |
|---|---|---|
| Carbon dioxide ($CO_2$) - - | from 44 | to 52 |
| Carbon monoxide (CO) - | „ 16 | „ 10 |
| Nitrogen (N) - - - | „ 31 | „ 33 |
| Sulphuretted hydrogen ($H_2S$) - | „ 2 | „ 4 |
| Hydrogen (H) - - | „ 1½ | „ 3 |

A small quantity of marsh gas was sometimes found.

As a rule the quantity of carbon dioxide increased as the pressure was raised; the carbon monoxide decreasing.

The volume of the gaseous products was measured and found to be, at a temperature of 0° C. and a barometric pressure of 760 millimetres (29·92 in.), about 278 times the original volume of the powder, that is, the gramme of the dry service pebble powder produces about 278 cub. centims. of gas at the above temperature and pressure.

Solid products.

The solid products were collected, and analysis showed the

per-centage composition by weight, in the case of P. powder, to be— Solid products.

| | | | | | |
|---|---|---|---|---|---|
| Potassium carbonate ($K_2CO_3$) | - | from | 50 | to | 64 |
| " sulphate ($K_2SO_4$) | - | " | 9 | " | 15 |
| " hyposulphite ($K_2S_2O_3$) | | " | 3 | " | 32 |
| " monosulphide ($K_2S$) | - | " | 2 | " | 19 |
| Free sulphur (S) | - - | " | ½ | " | 8 |

besides other compounds in very small and perhaps accidental proportions.

The volume of the solid products at a temperature of 0° C. was found to be ·3 times the original volume of the powder, that is, each gramme of powder produced about ·3 cub. centims. of solid residue.

As a check on these results, the weight of the gaseous products was obtained by calculating the weight of the solid products from the results of their analysis, and then subtracting this from the total weight of powder. On the other hand from a consideration of the measurement of the volume of the gaseous products, combined with their analysis, their weight was calculated, and thence by difference the weight of the solid products. The amounts of the elementary substances before and after combustion were also compared.

The result of these calculations showed that the proportions by weight were for the service powders very nearly—

| | | |
|---|---|---|
| Solid products | - | 57 per cent. |
| Gaseous " | - - | 43 " |

Experiments were also made to determine the condition of the products shortly after explosion, which led to the conclusion that the solid products were in the fluid state shortly after firing. The importance of this in its probable effect on the capacity of the gas for doing work will be dealt with hereafter.

Experiments to determine the tension.

The object of these experiments was to determine the maximum tension when the vessel was completely filled with powder, and also to ascertain the law according to which the tension varied with the gravimetric density, that is, to establish a relation between tension, quantity of matter, and space.

Gravimetric density.

The *gravimetric density* of a charge of powder is the ratio between the weight of powder and the weight of water which

Gravimetric density.

would completely fill the space in rear of the projectile. It must be clearly distinguished from *specific gravity*, which bears its usual signification, and does not include the interstitial and other spaces.

The gravimetric density is usually expressed in terms of the number of cubic inches allowed to each pound of powder in the chamber. The following table is given to show the relation between the two :—

TABLE of DENSITIES and VOLUMES of CHARGES referred to Cubic Inches of Space per Pound of Powder.

| Cubic ins. per lb. | Gravimetric Densities. | Volumes. | Cubic ins. per lb. | Gravimetric Densities. | Volumes. | Cubic ins. per lb. | Gravimetric Densities. | Volumes. |
|---|---|---|---|---|---|---|---|---|
| 20 | 1·386 | ·721 | 32 | ·866 | 1·155 | 45 | ·616 | 1·623 |
| 21 | 1·320 | ·757 | 33 | ·840 | 1·190 | 46 | ·603 | 1·658 |
| 22 | 1·260 | ·794 | 34 | ·816 | 1·225 | 47 | ·590 | 1·695 |
| 23 | 1·206 | ·829 | 35 | ·792 | 1·263 | 48 | ·578 | 1·730 |
| 24 | 1·155 | ·866 | 36 | ·770 | 1·299 | 49 | ·566 | 1·767 |
| 25 | 1·109 | ·902 | 37 | ·749 | 1·335 | 50 | ·554 | 1·805 |
| 26 | 1·066 | ·938 | 38 | ·730 | 1·370 | 51 | ·544 | 1·838 |
| 27 | 1·027 | ·974 | 39 | ·711 | 1·406 | 52 | ·533 | 1·876 |
| 27·73 | 1·000 | 1·000 | 40 | ·693 | 1·443 | 53 | ·523 | 1·912 |
| 28 | ·990 | 1·010 | 41 | ·676 | 1·479 | 54 | ·513 | 1·949 |
| 29 | ·956 | 1·046 | 42 | ·660 | 1·515 | 55·46 | ·500 | 2·000 |
| 30 | ·924 | 1·082 | 43 | ·645 | 1·550 | | | |
| 31 | ·894 | 1·118 | 44 | ·630 | 1·587 | | | |

Crusher gauge.

The apparatus used to measure the tension of the gas is known as the crusher gauge, and consist of a screw plug of steel (Figs. 1 and 2), which admits of a cylinder of copper or other material (A) being placed in the small chamber (B), the entrance to the chamber is closed by the movable piston (C), and the admission of the gas is prevented by means of the gas check (D). When the powder is fired, the gas acts upon the base of the piston and compresses the cylinder. The amount of compression of the cylinder is read off by a micro-

meter, and serves as an index to the force exerted, the relation between the compression and the pressure necessary to produce it being previously carefully determined. In some cases to insure accuracy the copper cylinder is crushed, before insertion, to a pressure just below that which it is expected to record. Crusher gauge.

THE CRUSHER GAUGE.

Fig. 1.

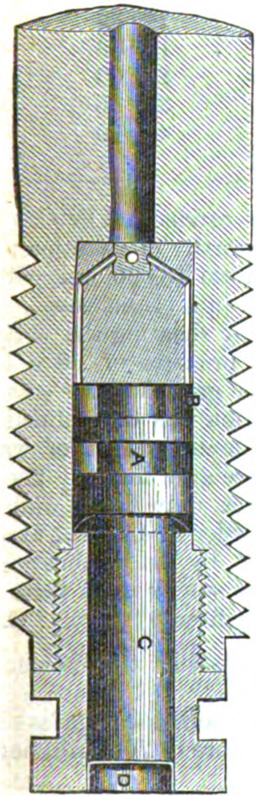
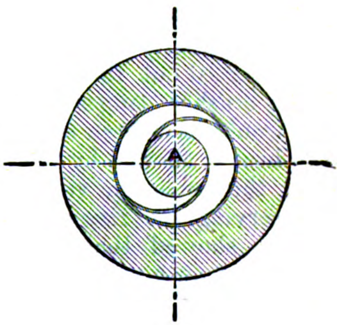



Fig. 2.




The pressures actually observed corresponding to various densities were plotted to scale, and a curve being drawn

Relation between pressure and density.

through them, the following table was derived, which shows the results for P. powder.

| Mean Density of Products of Combustion. | Corresponding Pressure in Tons per Square Inch. |
|---|---|
| ·10 - - - | 1·47 |
| ·20 - - - | 3·26 |
| ·30 - - - | 5·33 |
| ·40 - - - | 7·75 |
| ·50 - - - | 10·69 |
| ·60 - - - | 14·39 |
| ·70 - - - | 19·09 |
| ·80 - - - | 25·03 |
| ·90 - - - | 32·46 |
| 1·00 - - - | 41·70 |

In the second series of experiments carried out by Captain A. Noble at Elswick the following is worthy of attention :—

9,000 grs. pebble, and 4,000 F.G., total 13,000 grs., with a gravimetric density of 1·21, were fired in a closed vessel. The pressure forced out the closing plugs by shearing the threads, and the crusher gauges indicated a pressure of 56·8 tons, which would have been exceeded if the gases had not escaped.

Determination of heat developed.

The heat generated by the combustion was determined by placing the explosion vessel in a known weight of water, and observing the rise of temperature after firing. The experiments showed that it varied not only with different powders, but even with the same powder in different experiments, and that the amount developed by the combustion of one gramme of dry pebble powder was sufficient to raise the temperature of 721·4 grammes of water from 0° C. to 1° C.

Relation between tension and density.

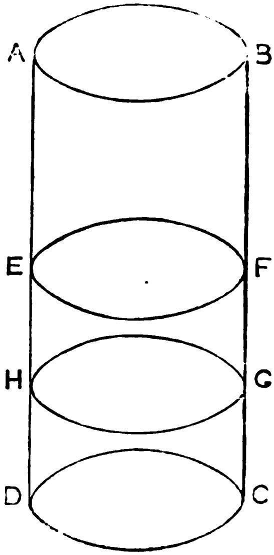
It has been seen that in a closed vessel at the moment of explosion 1 gramme of powder gives—

1. About 43 per cent. by weight of permanent gases occupying at 0° C., and under a pressure of 760 millimetres, a volume of about 278 cub. cent.
2. About 57 per cent. by weight of liquid product, occupying when in the solid form, and at 0° C., a volume of about ·3 cub. cent.

Relation between pressure and density.

Let ABCD represent the interior of the vessel of volume $v$. Let CDEF represent the volume of a given charge of powder placed in the vessel. Let $\delta$ be the ratio which the volume CDEF bears to ABCD, and let CDHG ($v \alpha \delta$ suppose) be the volume occupied by the liquid products at the moment and temperature of explosion.

Fig. 3.




On explosion, we have the space CDHG $= v \alpha \delta$ occupied by the fluid residue, and the space ABHG $= v\ (1 - \alpha \delta)$ by the permanent gases. Hence, since the tension of the permanent gases will vary directly as their density, we have, if $p$ represent the pressure and D the density,

$$p = \text{RD} \quad . \quad . \quad (1)$$

where R is a constant.

Now suppose the charge exploded in the chamber to be increased. In this case not only is the density of the permanent gases increased on account of a larger quantity being generated, but the density is still further added to from the gases being confined in a smaller space; the liquid residue CDHG being increased in a like proportion with the charge

$$\left(\text{D in fact varying as } \frac{\text{volume of powder}}{\text{volume occupied by gases}} = \frac{\delta}{1 - \alpha \delta}\right)$$

we have

$$p = \text{R} \times \frac{\delta}{1 - \alpha \delta} \quad . \quad . \quad . \quad . \quad (2),$$

or if $p_0$, $\delta_0$ be corresponding known values of $p$ and $\delta$

$$p = \frac{p_0\,(1 - \alpha \delta_0),}{{}_0} \times \frac{\delta}{1 - \alpha \delta} \quad . \quad . \quad . \quad (3),$$

then $\alpha$ can be determined, if values are found by experiment for $p$ and $\delta$. The value of $\alpha$ obtained was found to be ·65, but various considerations lead to the conclusion that $\alpha =$ ·57 is more near the truth.

Relation between pressure and density.

In other words, the liquid residue obtained by the combustion of 1 gramme of powder occupies ·57 cub. centims.

The results are tabulated in the following table, and show how closely the results agree with the tensions actually observed.

TABLE showing the Comparison between the Pressures actually observed in a close Vessel and those calculated from the Formula $p = p_0 \frac{1 - \alpha \delta}{\delta_0} \times \frac{\delta}{1 - \alpha \delta}$.

| Density of Products of Combustion. | Value of $p$ from direct Observation. | Value of $p$ from Equation when $\alpha$ = ·65. | Value of $p$ from Equation when $\alpha$ = ·57. |
|---|---|---|---|
| ·10 | 1·47 | 1·565 | 1·96 |
| ·20 | 3·26 | 3·363 | 4·17 |
| ·30 | 5·33 | 5·452 | 6·69 |
| ·40 | 7·75 | 7·908 | 9·58 |
| ·50 | 10·69 | 10·837 | 12·93 |
| ·60 | 14·39 | 14·390 | 16·86 |
| ·70 | 19·09 | 18·791 | 21·54 |
| ·80 | 25·03 | 24·383 | 27·19 |
| ·90 | 32·46 | 31·728 | 34·17 |
| 1·00 | 41·70 | 41·698 | 43·00 |

This table is of great practical importance, since it shows that the pressure can be reduced by giving the powder more room (air-spacing), and it also indicates the increase of pressure when it is compressed (front charge in a double-loaded gun).

Temperature of explosion.

In the case of a permanent gas, if $p$ is the pressure, $v$ the volume, $t$ the absolute temperature, and R a constant, we have the well-known law for permanent gases—

$$p\, v = \mathrm{R}\, t,$$

by means of which, and using the experimental results already quoted, the temperature was calculated to be about 2,200° C. This result is not far removed from the truth for the principal powders experimented with. This temperature, even in one and the same powder, cannot be supposed to be always identical.

## ACTION IN THE BORES OF GUNS.

American experiments.

Experiments to determine the pressure in the bores of guns are not of recent origin.

American experiments.

The most noticeable which have occurred of late years are those of Rodman in America, who may be considered to have originated the methods now employed. To Rodman is due the credit of applying a simple method of measuring the pressure directly by means of a gauge fixed in a hole in the gun. The instrument used by him is known as the Rodman gauge, and differs from the crusher gauge (which is a modification of it) in that the pressure causes a knife to make an indent in the copper instead of crushing it. The Rodman gauge is now used on the Continent, and it is a matter of opinion whether it is not more sensitive than the crusher gauge.

Rodman also pointed out that by proportioning the size of grain to the gun the strain on the gun might be reduced without any corresponding loss of velocity.

As long since as 1845, Captain Mordecai of the United States Ordnance Department drew attention to the influence of the density and size of grain on combustion and ignition, and to the advantage of air spacing in reducing the strain on the gun without any great loss of velocity.*

English experiments.

Systematic experiment in England did not commence until 1869, when the Committee on Explosives was appointed. Their experiments are exceedingly valuable, and confirm generally the American investigations.

The means used to determine the pressure in the bore of a gun were of two distinct kinds, viz. :—

1. The direct method.
2. The indirect method.

The direct method consists in measuring the pressure directly by means of crusher gauges inserted in the walls of the gun at different positions in the bore. The indirect plan is to determine the time at which the projectile passes certain fixed points in the bore; thence are deduced the velocities from the seat of the shot to the muzzle, and finally are obtained the gaseous pressures necessary to generate the observed velocities. The instrument used to determine the times is known as the chronoscope, and will be found described in the Treatise on the Construction of Ordnance, 1879, p. 350.

The two systems of experimenting not only serve as a check on one another, but are also complementary. The crusher

* Report of Experiments on Gunpowder made at Washington Arsenal in 1843, and 1844, by Captain Alfred Mordecai.

Systems of experimenting.

gauge registers the local pressure, which may be abnormally high (as will be hereafter explained), and is not given by the chronoscope. The chronoscope gives the mean pressure, or in other words, sums up all the infinitesimal impulses communicated to the shot, without giving any clue to the local action.

Object of measuring pressure.

The object to be attained by measuring the pressure in the bore is two-fold.

1. We wish to know which is the most useful description of powder, that is, the kind of powder which communicates the greatest amount of energy to the shot while putting a low maximum strain on the gun.

2. It is desired to ascertain the pressure at different points of the bore with a view of determining how the strength of the gun should be proportioned.

With regard to the first point, it may be, perhaps, useful to show the connexion between pressure and energy.

Work done.

Let a pressure of P lbs. be applied through a space of $s$ feet to a body of mass M and weight W lbs. Then the "work done" is represented by $P \times s$, and is measured in this case in foot pounds.

If $f$ be the velocity added on in each second, or the acceleration in the mass M due to the pressure P, and $v$ be the velocity at the end of the space $s$, we have the following well known relations:—

$$v^2 = 2fs$$

$$\text{and } P = M.f.$$

$$\text{Hence } P\,s = M\,f \times \frac{v^2}{2f} = \frac{Mv^2}{2}.$$

$$\text{But } M = \frac{W}{g}.$$

Where $g$ is the velocity added on in each second = 32·19 ft.

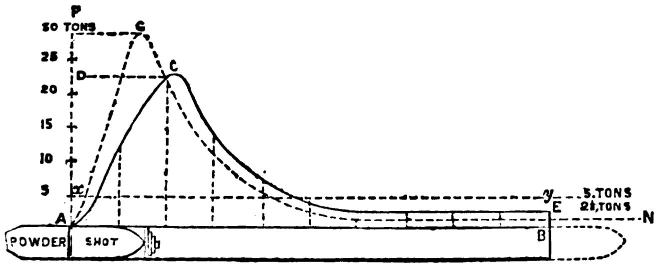
$$\therefore P\,s = \frac{Wv^2}{2g}.$$

This quantity $\frac{Wv^2}{2g}$ is a correct measure of the "work done," and is called the kinetic energy or *vis viva* of the body.

Having established the fact that the work done depends upon the pressure and the space through which it is exerted, we can examine the various ways in which these can be combined.

In fig. 4:— **Curve of pressures.**

FIG. 4.




let space be measured along the line AB, and pressure along lines at right angles to it. Then, if a uniform pressure = A$x$ be applied to the shot at every point of the bore, the work done will be represented by the area of the rectangle A$xy$B, since this equals A$x$ × AB.

The same work can also be done by a varying pressure, such as that represented by the curve ACE, or by the dotted curve AGN, so long as the area enclosed by the solid curve = the area included by the dotted curve = the area A$xy$B.

The powder which does the most work will be that of which the pressure curve includes the greatest area.

We now propose to discuss this pressure curve. Why should it be a curve and not a straight line similar to $xy$? The explanation of this depends upon the following laws:—*

**Laws of permanent gases.**

1. For the same quantity of gas, at the same temperature, the pressure varies inversely with the volume (Boyle's law).

2. Again, air, or any other permanent gas, under a constant pressure, is uniformly expanded by an increase, and uniformly contracted by a decrease of temperature. If the *pressure* remain constant, the volume of gas is doubled by an increase of 273° C. (480° F.) in temperature and every additional 273° C. increases its original volume once. If the *volume* remain constant, its tension or expansive force is doubled by a similar increase of temperature (Gay-Lussac's law).

* The London Science Class-book, "Thermodynamics," by R. Wormell.

Laws of permanent gases.

3. When a permanent gas expands doing work there is a fall of temperature, and the heat expended is the exact equivalent of the work done.

Now as before explained the pressure and volume of gas obtained by exploding a given quantity of powder are known, and we may make the following assumptions:—

1. That the gases expand without addition or subtraction of heat.
2. That the gases expand, drawing heat during their expansion from the non-gaseous portions.

Explanation of diagram.

The results of these assumptions are shown on the diagram, together with the tensions actually observed in the bores of guns, and also the tensions in closed vessels, which would be those observed if the gases expanded without doing work.

Consideration of this diagram leads to points of great interest and utility.

The curve marked A represents the tensions deduced from experiments in a closed vessel, and may be taken to represent the pressures that would exist were the products of combustion allowed to expand in a vessel impervious to heat and without production of work.

The curve marked B gives the tensions that would exist in the bore of a gun, if we suppose the powder, entirely filling the chamber and of density equal to that of water, to be completely consumed before the projectile is moved from its place and to expand in a gun impervious to heat.

The difference between the curves A and B represents the loss of energy due to work expended.

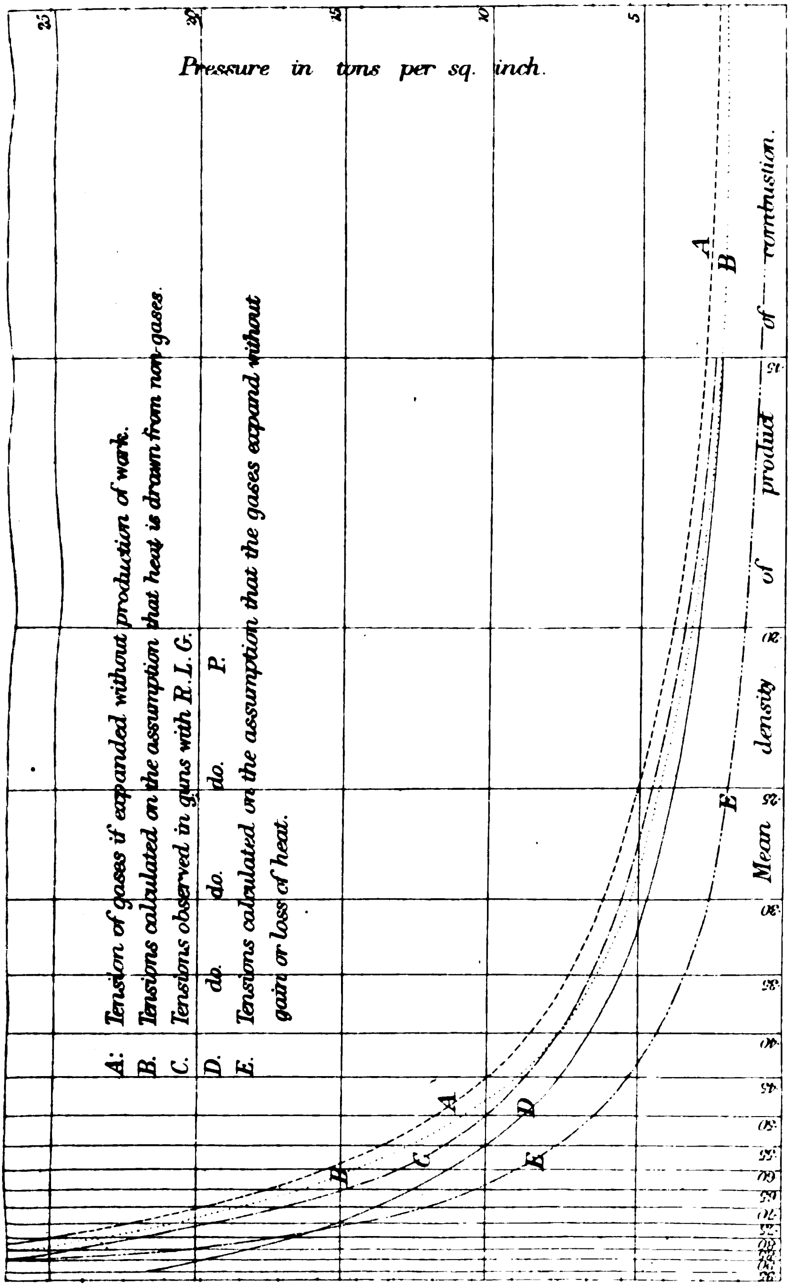
The area between the curve B and the axis of abscissæ represents the whole work which it is possible to obtain from powder. The curve E represents the tensions on the assumption that no heat is derived from the non-gases.

The great importance of the non-gases is represented by the area between the curves B and E.

The curves C and D represent the tensions actually observed with R.L.G. and P. powders respectively in the bores of guns, of which more hereafter.

Work done by powder.

Since the area between the curve B and the axis of abscissæ represents the work which can be done by powder, it is of the utmost importance to find the value of that area for a unit mass (1 lb.) of powder. This has been done on the assumption that one gramme of dry powder occupies a volume




*To face page 98.*

Dangerfield Lith 22 Bedford St Covent Garden

of 1 cubic centimetre, and that the initial tension is 43 tons. The results are shown in the following table :— Work done by powder.

| Density of Products of Combustion. | No. of Volumes of Expansion. | Total Work in Foot Tons that the Gunpowder is capable of realising per lb. burned. |
|---|---|---|
| ·90 | 1·1111 | 9·64 |
| ·80 | 1·2500 | 19·23 |
| ·70 | 1·4286 | 28·73 |
| ·60 | 1·6667 | 38·56 |
| ·50 | 2·000 | 49·05 |
| ·40 | 2·500 | 60·64 |
| ·30 | 3·3333 | 74·21 |
| ·20 | 5·0000 | 91·38 |
| ·10 | 10·0000 | 117·76 |

To enable this result to be made use of, a further table is added together with an example of its use :—

TABLE showing Work done per POUND of DRY POWDER in a GUN.

| No. of Volumes of Expansion in the Bore. | Total Work the Powder is capable of realising per lb. burnt in Ft. Tons. | No. of Volumes of Expansion in the Bore. | Total Work the Powder is capable of realising per lb. burnt in Ft. Tons. | No. of Volumes of Expansion in the Bore. | Total Work the Powder is capable of realising per lb. burnt in Ft. Tons. |
|---|---|---|---|---|---|
| 1·02 | 1·936 | 2·1 | 51·673 | 6·4 | 101·145 |
| 1·04 | 3·782 | 2·2 | 54·132 | 6·8 | 103·480 |
| 1·06 | 5·547 | 2·3 | 56·439 | 7·2 | 105·655 |
| 1·08 | 7·234 | 2·4 | 58·605 | 7·6 | 107·688 |
| 1·10 | 8·852 | 2·5 | 60·642 | 8·0 | 109·600 |
| 1·12 | 10·406 | 2·6 | 62·563 | 8·4 | 111·404 |
| 1·14 | 11·899 | 2·7 | 64·385 | 8·8 | 113·114 |
| 1·16 | 13·338 | 2·8 | 66·119 | 9·2 | 114·739 |
| 1·18 | 14·725 | 2·9 | 67·771 | 9·6 | 116·284 |
| 1·20 | 16·063 | 3·0 | 69·347 | 10·0 | 117·757 |
| 1·24 | 18·614 | 3·2 | 72·301 | 11·0 | 121·165 |
| 1·28 | 21·001 | 3·4 | 75·027 | 12·0 | 124·239 |
| 1·32 | 23·246 | 3·6 | 77·553 | 13·0 | 127·036 |
| 1·36 | 25·371 | 3·8 | 79·905 | 14·0 | 129·602 |
| 1·40 | 27·380 | 4·0 | 82·107 | 15·0 | 131·970 |
| 1·44 | 29·291 | 4·2 | 84·176 | 16·0 | 134·168 |
| 1·48 | 31·109 | 4·4 | 86·128 | 17·0 | 136·218 |
| 1·52 | 32·843 | 4·6 | 87·975 | 18·0 | 138·138 |
| 1·56 | 34·500 | 4·8 | 89·724 | 19·0 | 139·944 |
| 1·60 | 36·086 | 5·0 | 91·385 | 20·0 | 141·647 |
| 1·68 | 39·069 | 5·2 | 92·968 | 22·0 | 144·788 |
| 1·76 | 41·827 | 5·4 | 94·479 | 25·0 | 148·953 |
| 1·84 | 44·394 | 5·6 | 95·925 | 30·0 | 154·800 |
| 1·92 | 46·795 | 5·8 | 97·310 | 40·0 | 163·828 |
| 2·00 | 49·050 | 6·0 | 98·638 | 50·0 | 170·671 |

Work done.

The experiments hitherto carried out have tended to show that with different kinds of powder the pressure at any given density and the capacity for performing work does not materially vary.

By means of the above table we can calculate the maximum work that can possibly be obtained in any gun by a given charge of powder, when the gravimetric density is unity, and the volume 27·7 cub. in. per lb. (p. 90).

Maximum work in 9-in. gun.

EXAMPLE.—What is the maximum work that can possibly be done by 50 lbs. of P. powder in the 9-in. M.L. gun? (The length of the bore is 125 ins.)

$$\text{Volume of bore} = \frac{\pi}{4} \times 81 \times 125 \text{ cub. ins.,}$$

$$\text{volume of charge (50 lbs.)} = 50 \times 27 \cdot 7 \text{ cub. ins.;}$$

so that the number of the volumes of expansion of the powder charge contained in the bore of the gun are

$$\frac{\pi \times 81 \times 125}{200 \times 27 \cdot 7} = 5 \cdot 74.$$

From the table, then (by proportional parts), it will be seen that the *maximum* work capable of being performed by the charge of 50 lbs. of P. powder in the 9-in. M.L.R. gun

$$= 50 \times 96 \cdot 9 = 4845 \text{ ft. tons.}$$

But the actual muzzle velocity of the 9-in. gun, with a 250-lb. projectile and 50 lbs. of P. powder, is about 1420 f.s.; so that the muzzle energy communicated to the projectile is—

$$\frac{W v^2}{2240 \times 2g} = \frac{250 \times (1420)^2}{4480 \times 32 \cdot 2} = 3494 \text{ ft. tons.}$$

A comparison of this with the maximum work that could theoretically be effected by the charge, shows that there is a deficiency of 929 ft. tons of energy not realized in practice. This is due to the projectile moving before the complete combustion of the charge and to the absorption of heat by the gun. Hence the longer the motion of the projectile is delayed, whether from its weight or otherwise, and the more rapid the explosion of the powder, the more nearly will the maximum theoretical effect be realised. With service conditions, the heavier the gun the less the proportionate amount of heat

absorbed. In the 9-in. gun the percentage of maximum effect actually realised is—

$$\frac{349400}{4845} = 72 \cdot 1$$

This is called the *factor of effect* for this particular gun and charge. **Factor of effect.**

EXAMPLE.—Find approximately the muzzle velocity of the 38-ton gun of 12·5 ins., when firing an 800 lb. projectile with 110 lbs. of P. powder. (Length of bore 198 ins.) **Determination of muzzle velocity.**

The number of volumes of expansion of charge—

$$= \frac{\pi \times (12 \cdot 5)^2 \times 198}{4 \times 110 \times 27 \cdot 7} = 7 \cdot 97,$$

then by the table (p. 99) the maximum work capable of being performed by the charge is—

$$110 \times 109 \cdot 45 = 12039 \cdot 5 \text{ ft. tons.}$$

Assuming that the factor of effect for this gun and charge have been experimentally found to be 87, a very close approximation to the muzzle velocity can be obtained.

From the formula, p. 96, we have—

$$\frac{W\, v^2}{2240 \times 2g} = \text{energy in foot tons.}$$

$$\therefore \frac{800 \times v^2}{2240 \times 2 \times 32 \cdot 2} = 12039 \cdot 5 \times \frac{87}{100}.$$

$$\therefore \text{muzzle velocity} = \sqrt{\frac{2 \times 32 \cdot 2 \times 2240 \times 12039 \cdot 5 \times 87}{800 \times 100}}$$

$$= 1369 \text{ f.s.}$$

The factor of effect in any particular case depends on the nature of the powder, method of ignition adopted, the weight of the projectile, and the means of giving rotation, besides the amount of air space allowed for the cartridge. **Factor of effect.**

## VARIATIONS IN THE ACTION.

For a given calibre and weight of projectile there are, speaking generally, three distinct ways in which the energy actually realised can be varied. These are—

1. By varying the powder.
2. By modifying the gun.

3. By altering the weight of the charge, or its gravimetric density, which is called air-spacing.

*Effect of varying Powder.*

Work done in a gun depends upon the powder.

The nature of the powder exercises great influence on the muzzle energy realised per pound of powder.

Referring to Fig. 4 it will be observed that the work to be done is represented by the area $Axy$ B, and that with a perfect ideal powder the pressure should remain constant and equal to $Ax$.

The important points are the maximum pressure and the rate at which the pressure changes, which depend upon the ignition and combustion of the powder. With the same gravimetric density these vary with—

1. The size and shape of the grain.
2. The density and hardness of the powder.
3. The amount of glazing.
4. The quantity of moisture.

Size and shape of grain.

The size and shape of the grain vary greatly in different powders (table, p. 106), and exercise an important influence as will be seen from the following table and from the diagram opposite.

TABLE showing the Results of Explosion of P. and R.L.G. Powder.

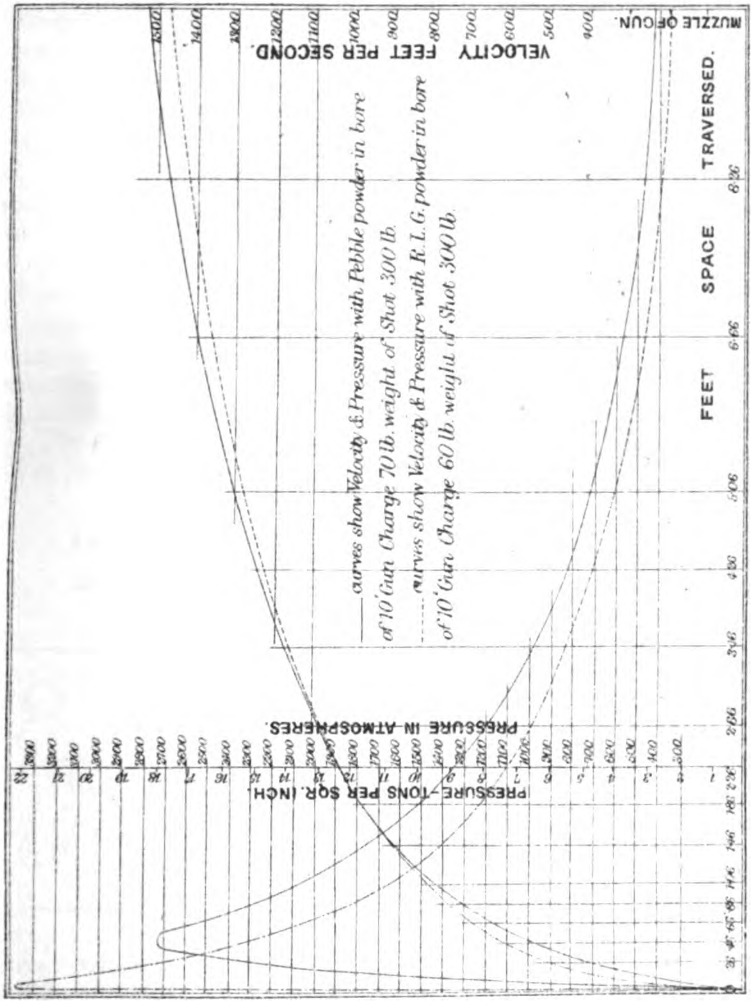
| Charge of powder. | Weight of projectile. | Muzzle velocity. | Maximum pressure in the chamber. | Time of max. press. after ignition. | Distance traversed in that time by projectile. |
|---|---|---|---|---|---|
| | lbs. | f.s. | tons per sq. in. | sec. | ins. |
| 70 lbs. P. - | 300 | 1527 | 18 | ·00437 | 6·0 |
| 60 lbs. R.L.G. | 300 | 1480 | 22 | ·00070 | ·6 |

This may be explained as follows:—

Suppose a powder similar in all respects except in the size and shape of the grains; then conversion of the powder into gas depends on the rate of ignition of the grains and the time of combustion of each grain.

The rate of ignition of the grains depends on the facility with which the flame can penetrate to contiguous grains, *i.e.*,

**PRESSURE AND VELOCITY CURVES WITH PEBBLE AND R.L.G. POWDERS.**




*To face page 102.*

Dangerfield Lith 22 Bedford St Covent Garden

**Size and shape of grain.**

on the magnitude of the interstices between the grains, depending principally on the shape of the grains; while the time of combustion depends on the bulk or size of the grains themselves, *i.e.*, the smaller the *size* the quicker the combustion. These conditions are to a certain extent opposed to one another; so that it will readily be understood that for a given quantity of powder there is some shape and size of grain which will give uniformity of ignition combined with the required rapidity of combustion.

This is the object to be attained, viz., to ignite the charge uniformly throughout, so that the pressure may be as nearly as possible the same at every point in the powder chamber, and then to insure that the combustion shall take place at the uniform rate required. This necessitates uniform interstices of the proper size, and grains of similar size and shape.

**Prismatic powder.**

These considerations led to the adoption of mammoth powder in America, of pebble powder in England, and of a form of powder known as prismatic, figs. 5 and 6, which is much used on the Continent, and being regularly packed gives very good results. The figure below shows the size and shape for the description, having seven perforations.

FIG. 5.

Plan.

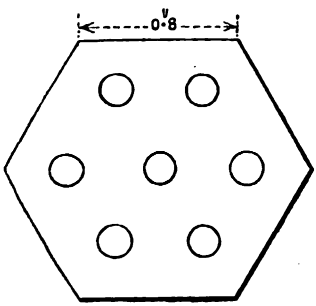
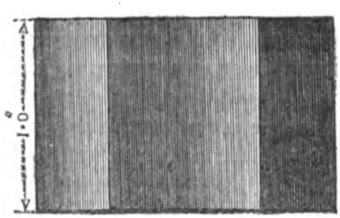



FIG. 6.

Elevation.




Prismatic powder. (Full size.)

The great regularity in the action of this powder will be seen by reference to p. 175, in which the accuracy of the Krupp guns is mentioned.

The combustion and ignition of the charge are also materially affected by the density and hardness of the grains of powder.

**Density and hardness.**

The density depends on the amount of pressure to which the powder meal has been subjected during manufacture, and is now accurately arrived at by means of a mercury densimeter, in which the weight of a given volume of powder is compared with that of an equal volume of mercury, the density of mercury (corrected according to the readings of a barometer and thermometer at the time) being known, that of the powder is easily calculated. The hardness is greatly affected by the amount of moisture present in the meal when pressed. One term applies to the mass, while the other refers more particularly to the surface of the grains. A dense powder may be generally stated to be a slow-burning powder, while a hard one is slow lighting. Density retards the combustion, both because there is more matter in the same volume, and consequently more powder to be consumed in proportion to the ignited surface of the grain, and also because the heated gas finds greater difficulty in penetrating the solid mass of the grain. A hard powder need not of necessity be very dense; it is even possible, by pressing it in a moist state, to obtain a very hard powder which shall at the same time be light and porous in the interior of the grain.

**Fossano powder.**

Considerations of the varying effect which density exercises on the action has led to the introduction in Italy of a powder called "Fossano" or "Progressive."

The manufacture of the Fossano powder is peculiar, and is believed to be somewhat as follows. After passing through the first stages of manufacture and being brought to the condition of "meal powder," it is pressed into cakes which have a density of 1·79. The cake is then broken up into irregular grains of about an eighth to a quarter of an inch in thickness. The grains are then mixed with a certain quantity of meal powder and the whole mass is pressed into a cake which has a density of 1·776. This second cake is then broken up into tolerably regular pieces about $2\frac{1}{8}$ inches square by $1\frac{3}{4}$ thick. These grains, if they can so be called, are therefore composed of a number of small pieces with a higher density placed like the raisins in a plum-pudding in a sort of conglomerated powder material of a lower density. The intention of the inventors of this powder was to bring about a condition of affairs, in which more gas would be produced in a given time when the powder has been partly burnt than at the commencement of its ignition.

COMPARISON of $P^2$ and Fossano Progressive Powder in the 100-Ton R.M.L. Armstrong Gun.

Fossano powder.

| Powder. | Charge. | Total Energy. | Pressure on Chamber. |
|---|---|---|---|
| | lbs. | Tons. | Tons. |
| $P^2$ - - - - | 397 | 29,678 | 17·15 |
| Fossano - - - | 441 | 29,032 | 10·00 |
| $P^2$ - - - - | 441 | 33,800 | 17·80 |
| Fossano - - - | 469 | 32,919 | 13·15 |
| $P^2$ - - - - | 469 | 36,710 | 20·80 |
| Fossano - - - | 529 | 37,216 | 15·80 |
| „ - - - | 551 | 38,313 | 17·37 |

The densities of different powders are given in tables below.

Glazing and Moisture.

Glazing, like hardness, retards the ignition of the grains.

The amount of moisture in the powder has tne effect of modifying its time of explosion. The accompanying table shows the effect of moisture in powder: as the per-centage of moistuie increases, combustion is retarded, and the pressure in the gun and the muzzle velocity of the projectile are decreased.

TABLE showing the Effect of Moisture in Powder on Muzzle Velocity and Pressure in the Gun.*

| Sample of powder. | Per-centage of moisture. | Muzzle velocity in ft. secs. | Maximum pressure in the bore (ft. tons). |
|---|---|---|---|
| Pebble, $\frac{5}{8}$ in. - | ·8 | 1,537 | 21·38 |
| | 1·0 | 1,524 | 20·18 |
| | 1·2 | 1,512 | 19·21 |
| | 1·4 | 1,502 | 18·18 |

* Researches on Explosives, Noble and Abel, p. 122.

Service powders.

## TABLE of Densities and Muzzle Velocities for Service (Rifle) Powders.

| Description of Powder. | Size. | Arm in which proved. | Density. From. | Density. To. | Muzzle Velocity. From. | Muzzle Velocity. To. | Max. Pressure. |
|---|---|---|---|---|---|---|---|
| | | | | | f.s. | f.s. | Tons. |
| R.F.G. - - | 12 to 20 meshes to an inch. | Snider rifle - | 1·58 | 1·62 | 1,250 | 1,290 | — |
| R.F.G.² - - | Ditto - - | Martini - Henry rifle. | 1·72 | 1·75 | 1,290 | 1,340 | — |
| R.L.G. - - | 4 to 8 mesh - | 9-pr. rifled M.L. gun. | 1·67 | 1·69 | 1,385 | 1,435 | — |
| R.L.G.² - - | 3 to 6 „ - | Ditto - - | 1·66 | * | 1,390 | * | 15 |
| "P." (Pebble) | ⅝ inch cubes - | 8-inch rifled M.L. gun 35 lbs. charge. | 1·78 | 1·82 | 1,420 | 1,480 | 20 |
| "P.²"(Cubical) | 1½ inch cubes - | 38-ton R.M.L. gun (chamber) 200 lbs. charge. | 1·75 | * | 1,530 | * | 22 |

* No *higher* limits of density or velocity are laid down for these powders, but those properties tend to counteract one another. The maximum pressures allowed also practically furnish higher limits of velocity.

Foreign powders.

## TABLE showing Density and Size of Grain of Powders used with Foreign Rifled Ordnance.

| Description of Powder. | Size of Grain. | Mean Density. |
|---|---|---|
| American:— | | |
| Mammoth - | Irregular shape, diameter ·8″. | — |
| Hexagonal - - | ·7″ × ·75″ - | 1·75 |
| French:— | | |
| A.S. - - - | 1″·18 to 1″·57 cubes - | — |
| Wetteren - - | 0″·787 to 0″·984 cubes - | — |
| Do. - - | 0″·512 to 0″·630 „ - | — |
| German:— | | |
| Prismatic, with one perforation. | Height 1″ - - <br> Side of hexagon ¾″ - | 1·75 |
| Do. - - | Height 1″ - - <br> Side of hexagon 2″ - | 1·75 |
| Prismatic, with seven perforations. | Height 1″ - - <br> Side of hexagon ·8″ - | 1·67 |
| Italian:— | | |
| Fossano - - | $2\frac{1}{8}'' \times 2\frac{1}{8}'' \times 1\frac{3}{4}''$ - - | 1·776 |

*Effect of varying Gun.*

The points in the gun which can affect the muzzle energy realised are— Changes in muzzle energy.

1. Length of bore.
2. Windage.
3. Twist of rifling.
4. Position of vent.
5. Chamber.

As regards length of bore, it has been already shown, p. 97, that the work done depends upon the number of expansions, that is, upon the length of bore. It must be observed that after a certain point is reached, the work done corresponding to each additional expansion, becomes smaller and smaller. Again as the length of bore increases the energy absorbed in friction, &c., continually gets larger. Each of these considerations lead to the conclusion that for any particular kind of powder, &c., there is a length of bore which cannot profitably be exceeded. A reference to diagram (p. 102) will explain this point, and show that the increments of velocity gradually decrease as the projectile approaches the muzzle. Length of bore.

Windage is a source of loss of energy due to the escape of a certain portion of gas. Windage.

The effect of rifling is generally to reduce the muzzle energy of translation, a certain very small proportion of the total work being absorbed in giving rotation to the projectile, and by the necessarily increased friction. Rifling.

The following experiment with an 11-in. gun was carried out to ascertain the difference in the velocity and pressure with different descriptions of rifling.

| | Velocity. | Mean Pressure in Powder Chamber. |
|---|---|---|
| Increasing twist | - 1,461 feet | 18·7 tons. |
| Uniform „ | - 1,465 „ | 19·0 „ |

With small guns it has been found that pressure and velocity are increased, if the method of giving rotation is such that considerable force is required to push the projectile into the bore. This is probably due to the earlier and more complete combustion of the charge.

The great importance of uniform ignition has been already pointed out, so that the position of the vent or the point at which ignition commences, must also be of consequence. In the case of grain powders, with which the gas could with difficulty penetrate the charge, the best position for the vent Position of vent.

Position of vent.

was found by experiment to be at $\frac{4}{10}$ the length of cartridge from the rear.

The French and Germans have however for some years fitted rear axial vents to their guns, and apparently with marked success. With prismatic powders built up symmetrically with channels from end to end of the cartridge, the gas first developed can readily penetrate to the front of the charge and thus insure uniform ignition.

It will be convenient to consider the question of chambering after discussing the effect of air-spacing.

## *Air-spacing.*

French experiments.

The advantages of air-spacing were pointed out by a committee of officers of French Artillery about 1840, and were partially confirmed by Captain Mordecai in the United States during the years 1843 and 1844. In both cases the experiments took the form of a reduction in the diameter and a corresponding increase in the length of the cartridge. Captain Mordecai states that the French experiments showed "that " by reducing the diameter of the cartridge, the strain on the " gun may be greatly diminished." Later experiments, which owing to the recent advances in metallurgy and electricity have been more exact, have confirmed this result.

In the case of closed vessels, the relation between the pressure and the gravimetric density is shown in table (p. 94).

Committee on Explosives.

In the case of guns the following table giving the result of experiments carried out by the Committee on Explosives, shows the variation in the pressure as the gravimetric density and the charge are varied.

TABLE showing Experiments with 38-ton Gun, allowing Air-space.*

(Cubical powder, 1·5 ins.)

| Number of Round. | Charge. | Shot. | Muzzle Velocity. | $E$. Energy. | $P$. Mean Pressure in Powder-Chamber per sq. in. | $\frac{E}{P}$ | Length of Cartridge. | Cubic ins. Per Pound of powder. |
|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | f.s. | ft. tons. | tons. | | ins. | |
| 1 | 130† | 800 | 1,451 | 11,655 | 24·5 | 476·9 | 28·00 | 24·6 |
| 2 | 130† | 800 | 1,391 | 10,734 | 19·3 | 556·1 | 33·22 | 30·0 |
| 3 | 180† | 800 | 1,541 | 13,176 | 22·4 | 587·3 | 45·37 | 30·0 |
| 4 | 180‡ | 800 | 1,544 | 13,225 | 20·8 | 634·0 | 36·25 | 30·0 |

* Principles of Gunnery, by Major Sladen, p. 37.
† Gun unchambered. ‡ Gun chambered.

In round 2, the gravimetric density is diminished, and the useful length of the bore is also reduced, the result being a lower pressure and a corresponding loss of velocity. Air-spacing.

The reduction in the *mean* pressure in round 2 is due to the diminution in the initial pressure arising from the decrease in the gravimetric density. A loss in velocity follows necessarily from a lower mean pressure in any given length of bore.

This may be further exemplified by working out the Example on p. 100, when the space allotted to the charge is 30 cub. in. per lb. instead of 27·7. We shall have—

Volume of charge = $50 \times 27{\cdot}7$ = 1385 cubic inches,

and the number of volumes of expansion will be

$$\frac{\pi \times 81 \times 125}{1385 \times 4} = 5{\cdot}74\,;$$

but this is from a density ·924 instead of a density of one, hence the work done must be taken from an expansion 1·08 to an expansion 5·74, and this is equal to

$$96{\cdot}9 - 7{\cdot}23 = 89{\cdot}67 \text{ ft. tons.}$$

∴ The total work of which the charge is capable is

$$50 \times 89{\cdot}67 = 4483 \text{ ft. tons.}$$

The loss of available energy = 4845 — 4483 = 362 ft. tons.

Round 3 calls for no remarks.

If the charge of powder were increased beyond 180 lbs., the length of the cartridge would be increased, and ignition would probably cease to be uniform with the description of powder employed, which would give excessive pressures at particular points in the chamber. These high local pressures are known as wave pressures, and not being at present well understood must be carefully guarded against as being possible sources of danger with the proposed large charges. The shot would also approach nearer to the muzzle, so that the useful length of bore would be diminished, and the velocity would fall. Both these conditions are objectionable.

To obviate this, resort has been had to chambering the gun, by which the length of the charge can be kept within bounds. The results are shown in round 4. Here the loss in mean pressure in the powder chamber is fully counterbalanced by the increase in the useful length of the bore. Chambering.

The principle of chambering is applied to all the newer guns and the breech-loading system is that in which it can be most easily developed.

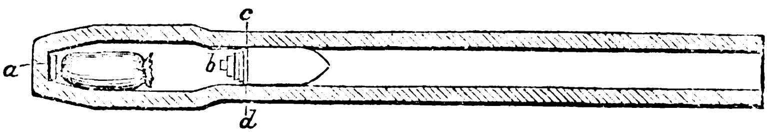
No chambered gun has yet been proved to destruction, and therefore the effect of chambering on the strength of the gun is an open question.

Large air-space.

It has been pointed out that the pressure is reduced as the density is diminished, and that this is done by either chambering the gun, or by not ramming the projectile close up to the powder. If this last plan be adopted it becomes of importance to determine whether, when the gases have a considerable space in which to expand, a large local pressure is not introduced. In other words, if the shot is not rammed home is there a probability of the gun bursting? The annexed diagram gives the results of experiments carried out by Captain A. Noble to settle this point.

AIR-SPACE EXPERIMENTS with 10-inch Gun.*

FIG. 7.

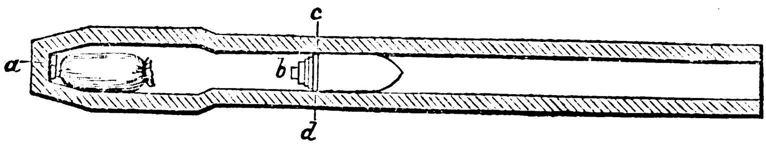



Charge 85 lbs. pebble powder.
Weight of shot 403 lbs.

At *a*. 11·7 tons.
„ *b*. Less than 10 tons.

At *c*. Less than 10 tons.
„ *d*. „ „

FIG. 8.

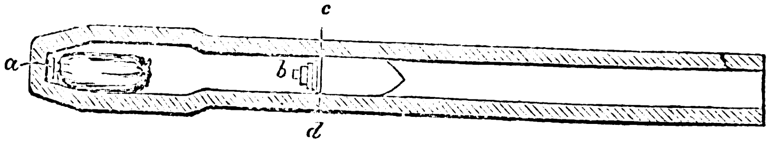



Charge 85 lbs. pebble powder.
Weight of shot 402 lbs.

At *a*. 10·1 tons.
„ *b*. Less than 10 tons.

At *c*. 7·6 tons.
„ *d*. 6· tons.

FIG. 9.




Charge 85 lbs. rifle large grain.
Weight of shot 402 lbs.

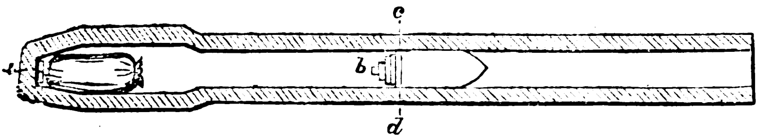
At *a*. 16·7 tons.
„ *b*. 35·3 tons.

At *c*. 25·5 tons.
„ *d*. 23·3 tons.

* Lecture delivered at the Royal Institution by F. J. Bramwell, Esq., F.R.S.

Large air-space.

FIG. 10.




Charge 85 lbs. pebble powder.
Weight of shot 402 lbs.

At *a*. Less than 10 tons.
„ *b*. 5·6 tons.

At *c*. Less than 8 tons.
„ *d*. Less than 8 tons.

The powder used in the first experiment, Fig. 7, was pebble powder, and occupying such a space as would give a pressure of about 20 tons to the square inch, and would impart to a 400 lb. projectile a muzzle velocity of 1,487 feet per second. The projectile was placed 2 feet away from the cartridge, that is to say, there was a 2 feet air-space: as the result, the velocity was only 1,240 feet per second instead of the 1,487, showing that the mean pressure must have been only 76 per cent. of that which would have prevailed if no air-space had been left; and further, so far from the maximum pressure having been even locally increased at the bottom of the bore of the gun it was but 11·7 tons, while at the base of the projectile it did not amount to 10 tons on the square inch.

In the next experiment, Fig. 8, the air-space was 4 feet; the muzzle velocity was only 1,067 feet, instead of the 1,487, showing that the average pressure was only 68½ per cent. of that which would have prevailed without an air-space. The pressures recorded were—at the bottom of the bore 10·15 tons, at the top of the projectile 7·6 tons, at the bottom 6 tons, and at the centre something below 10 tons.

These two experiments having totally failed to set up a local pressure, the next experiment, Fig. 9, was made not with pebble powder but with the rifle large grain. The air-space was again 4 feet; on this occasion the pressure at the bottom of the bore was 16·7 tons upon the square inch; on the upper part of the base of the projectile was 25·5 tons; in the centre of the projectile was 35·3 tons; at the bottom was 23·3 tons; while with this powder had the gun been fired without an air-space the pressures would have been from 27 to 30 tons. In these experiments no wad was used, and it was determined to make others with a disc wad. In the first instance, Fig. 10, 85 lbs. of pebble powder being employed, and a 6-feet air-space being left, the wad being close to the projectile, the muzzle velocity was 849 feet, the pressure at the bottom of the bore

under 10 tons, in the base of the shot at top under 8 tons, in the centre 5·6 tons, and at the bottom under 8 tons. The last experiment consisted in leaving a 2 feet air space between the cartridge and projectile, and a 4 feet air space between the projectile and the canted disc wad, while the muzzle velocity was 1,208 feet as compared with the 1,240 feet of the previous experiment with the 2 feet space; the pressure at the bottom of the bore was 11·1 tons as compared with 11·7 on the former occasion; while the pressure at the top of the base of the projectile was 7·9 tons, at its centre was 9·2 tons, and at its bottom 8·4 tons on the square inch.

On the other hand Captain Noble has found that, where there is a large air-space, the energy developed in the projectile is materially higher than that due to the expansion of the gases through the space traversed by the projectile. This is due to the ignited products (part of which are liquid and therefore possessing considerable mass) acquiring, while traversing the air-space, considerable energy which is communicated to the projectile by direct impact.

American experiments.

Recent experiments with small arms in the United States have also shown that a space between the powder and the bullet is not liable to burst the barrel.

# CHAPTER V.

## MOTION OF A PROJECTILE.

### DEFINITIONS.

The following definitions are used in Gunnery :—

1. *Axis of the Piece* :—An imaginary line passing down the centre of the bore.

2. *Axis of the Trunnions* : — An imaginary line passing through the centre of the trunnions at right angles to the axis of the piece.

3. *Trajectory* :—The curve described by the projectile in passing from the muzzle of the piece to the first point of impact.

4. *Line of Sight* :—An imaginary line passing through the sights of the piece and the point aimed at. This is also termed the "*Line of Fire.*"

5. *Plane of Sight* :—The vertical plane passing through the line of sight.

6. *Angle of Sight* :—The angle which the line of sight makes with the horizontal plane.

7. *Angle of Elevation* :—The angle which the line of sight makes with the axis of the piece.

8. *Quadrant Angle* :—The angle which the axis of the piece, when laid, makes with the horizontal plane, and termed "*Quadrant Elevation,*" or "*depression,*" according as the piece is laid above or below the horizontal plane.

9. *Line of Departure* :—The direction in which the projectile is moving on leaving the piece—in other words, a tangent to the trajectory at the muzzle.

10. *Plane of Departure* : — The vertical plane passing through the line of departure.

11. *Angle of Departure* :—The angle between the line of departure and the horizontal plane.

12. *Jump* :—The excess of the angle of departure above the quadrant angle.

13. *Angle of Projection* :—The angle between the line of departure and the line of sight.

14. *Angle of Descent* :—The angle which a tangent to the trajectory at the first point of impact makes with the horizontal plane.

15. *Range:*—The distance from the muzzle of the piece to the intersection of the trajectory with the line of sight.

16. *Lateral Deviation:*—The perpendicular distance of the point of impact of the projectile right or left of the plane of sight.

17. *Drift:*—The constant deflection of a projectile from the plane of departure due to the rotation imparted by the rifling of the piece. It is also called "*Derivation.*"

18. *Muzzle Velocity:*—The velocity of a projectile on leaving the piece.

19. *Remaining Velocity:*—The velocity of a projectile at any given point of its trajectory.

20. *Striking Velocity:*—The velocity of a projectile at the point of impact.

Definitions of the various descriptions of Artillery Fire will be found in the chapter on "Effects of Fire."

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## Resistance of the Air.

### *Experiments and Theory.*

Forces acting.

On leaving the bore a projectile fired from a gun has a certain amount of energy of translation impressed upon it, and it at once comes under the influence of two forces:—

1. The force of gravity.
2. The resistance of the air.

The effect of gravity on a projectile will not be discussed in this work.

The resistance of the air to projectiles moving in it with high velocities has long been known to be very considerable, and many attempts have been made to find a law which would account for the results observed in practical gunnery.

In 1860–1 the first experiments with ogival elongated projectiles were carried out by Professor Hélie.

He concluded that the results of these experiments "authorised him to consider that the resistance of the air was proportional to the cube of the velocity, at least as long as the axis of the projectile did not deviate much from the tangent to the trajectory described by its centre of gravity;" but it was not until Professor Bashforth carried out a series of systematic experiments with spherical and elongated projectiles by means of his Clock Chronograph that any *accurate* knowledge of the subject was obtained.*

Professor Bashforth's experiments.

Object.

The object of these experiments was to determine whether the resistance of the air varied as the *cube of the velocity*, and

* *Vide* Bashforth's "Motion of Projectiles."

whether it varied also as the *square of the diameter*, and with the form, of the projectile.

**Results.** The result showed that the resistance of the air varies with the form of the projectile; that for the same velocity and the same form, whether spherical or elongated, it varies exactly as the square of the diameter; also that for the same form and diameter it varies as the cube of the velocity only for velocities between certain narrow limits.

**Method.** The method consisted in measuring with extreme accuracy by means of electrical recording instruments the times of passing over successive *equal* spaces, in order to establish a relation between space and time, from which might be deduced the velocity and retardation at any instant.

Since the cubic law offers the greatest simplicity of calculation, Bashforth retained it for convenience as the basis for the calculation of remaining velocities, and represented the retardation in terms of the cube of the velocity and a variable coefficient depending on the velocity, form, weight and diameter of the projectile under certain given atmospherical conditions.

**Tabular form of coefficient.** From the results of his experiments Bashforth has calculated this coefficient for projectiles of unit weight and diameter, and with various forms of head. These will be found in his works.

Table I., p. 132, gives this coefficient (multiplied by $\overline{1000}|^3$ for convenience) for projectiles of the service form with ogival heads struck with a radius of $1\frac{1}{2}$ diameters, for velocities between 430 and 2250 f.s., the coefficient for any velocity $v$ being denoted by $K_v$.

Calling the retardation $f$ then for a projectile of unit weight and diameter,

$$f = K_v \cdot \frac{v^3}{(1000)^3}$$

Now by a well-known law the retardation varies directly as the resistance, and inversely as the weight of the projectile; and as stated above the resistance was found to vary with the square of the diameter; so that for a shot of weight $w$, and diameter $d$ the equation becomes

**Formula for Retardation.**

$$f = K_v \cdot \left(\frac{v}{1000}\right)^3 \cdot \frac{d^2}{w} \ldots\ldots (1).$$

**Resistance.** The resistance $R = m.f$ (where $m$ is the mass of the projectile), and $m = \frac{w}{g}$, therefore from (1)

$$R = K_v \cdot \left(\frac{v}{1000}\right)^3 \cdot \frac{d^2}{g} \ldots\ldots (2).$$

Resistance.

From which the actual value of this resistance in pounds has been calculated for service projectiles by Mr. Bashforth and will be found in Table II.

EXAMPLE.—What is the resistance of the air in lbs. to an ogival-headed projectile of 16 ins. in diameter, moving with a velocity of 1600 f.s.?

From equation (2),

$$R = K_{1600}\frac{d^2}{g}\cdot\left(\frac{v}{1000}\right)^3 = \frac{89.7\times(16)^2}{32\cdot 19}\left(\frac{1600}{1000}\right)^3 = 2922 \text{ lbs.}$$

An inspection of Table I. shows that $K_v$ is only constant for limited ranges of velocities, and therefore the resistance of the air varies as the cube of the velocity only for velocities within certain limits. It is to be observed that owing to the difficulty of obtaining trustworthy results from low velocities the values for velocities below 530 f.s. are not reliable.

Fluctuations in resistances.

A study of the values of K and of the resistances given in Tables I. and II. leads to the following conclusions:—

1. Between velocities of 430 to 830 f.s. the resistance of the air varies nearly as the square of the velocity.
2. Between the velocities of 830 and 1,000 f.s. K is nearly constant and = 75. The resistance therefore varies roughly as the cube of the velocity.
3. Above 1,000 f.s. the resistance increases very suddenly and rapidly, varying between 1,000 and 1,100 f.s. roughly as the 6th power of the velocity.
4. The rate at which the resistance varies again decreases above this point until another point between 1,200 and 1,250 f.s. is reached, where K is practically constant and the resistance varies as the cube of velocity.
5. The rate again decreases steadily, and between 1,400 and 1,500 it is about as the square of velocity.
6. Finally between 1,500 and 1,900 the minimum is reached, the resistance between these limits varying roughly as the 1·7th power of the velocity.
7. Above 1,900 the rate again increases steadily until 2,250 is reached, and here the resistance varies nearly as the cube of the velocity, K tending to become constant.

We may, therefore, until further experiments have been carried out, consider K to remain constant and equal to $K_{2250}$ = 66·6 for all velocities of ogival headed projectiles exceeding 2,250 f.s.

It should be mentioned that in the reduction of the experiments of 1867–8 the weight of a cubic foot of air was taken as 530·6 grains, but in the case of these later experiments as 534·22 grains, which is the weight of a cubic foot of dry air at 62° F. under a pressure of 30 inches of mercury. **Atmospheric conditions.**

When the range is considerable and the weight of the air differs sensibly from the above that weight must be taken into account if very accurate calculations are required.

The coefficients given in former tables must be multiplied by the factor 1·0068 to compare them with the new tables.

These fluctuations in the resistance are of great interest, and a study of Mr. Bashforth's results would seem to show that the resistance of the air is due to two or more concurrent fluctuating causes.

An interesting question here arises as to the extent to which Mr. Froude's experiments on fluid resistances can be applied to the case of a projectile moving through the air at high velocity. **Comparison with Mr. Froude's experiments.**

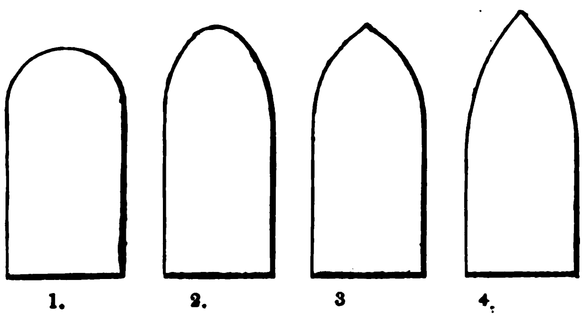
Although there is no evidence to explain satisfactorily the variations in the resistance, there would appear to be sufficient analogy in the two cases to justify the belief that it is due to —

1. Friction.
2. Wave and eddy making.

Further experiments, however, can alone decide the point.

The values of $K_v$ have also been determined for projectiles with the following forms of head, viz., (1) hemispherical, (2) hemispheroidal, (3) ogival of 1 diameter, and (4) ogival, of 2 diameters. **Influence of form of head.**

Fig. 1.



Effect of form of head.

The results obtained for a velocity of about 1,200 f.s. were as follows:—

| Form of head. | Coefficient of resistance $K_v$. |
|---|---|
| Hemispherical - - - | 133·8 |
| Hemispheroidal - - - | 105·0 |
| Ogival-head (1 diam.) - - | 110·9 |
| Ogival-head (2 diams.) - - | 104·9 |

Further experiments carried out with higher velocities give the following values for $K_v$ at a velocity of 1,700 f.s.:—

| | |
|---|---|
| Elongated projectile with ogival head ($1\frac{1}{2}$ diam.) | 83·0 |
| " " hemispherical head - | 113·6 |
| " " flat head - - | 173·5 |
| A spherical projectile - - - - | 121·6 |

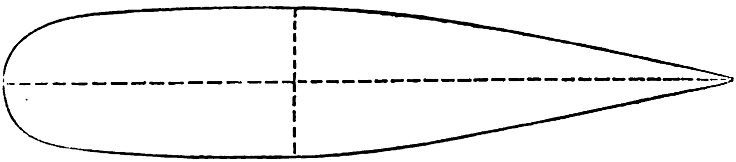
It was concluded that the resistance of the air to the flat head was the greatest, and to the ogival head of 2 diameters the least, of the forms experimented on.

The resistance of the air to the hemispheroidal and ogival heads differs so little that there is practically not much to choose between them. Professor Bashforth states that "the "slight variations in the resistances to the three latter forms "lead to the conclusion that the amount of resistance offered "by the air to the motion of elongated projectiles is little "affected by the more or less pointed apex, but depends "chiefly upon the form of head near its junction with the "cylindrical body of the projectile. In this neighbourhood "the forms of the hemispheroidal head and the ogival head "struck with a radius of 2 diameters are the same, and the "resistances are little different."*

Effect of form of base.

The resistance of the air is probably affected by the shape of its hinder as well as of its fore part. The form which would theoretically encounter the least resistance in passing through the air is given by Piobert, in his "Cours d'Artillerie," p. 15.

Fig. 2.



Its length is five times its greatest diameter, and its largest section is placed at $\frac{2}{5}$ths of its length from the base.

* Bashforth's "Motion of Projectiles," page 30.

Besides the considerations of the resistance of the air, the form also depends upon its suitability for the penetration of armour plates, which will be treated in a subsequent chapter. Both considerations lead to some form of ogival head, and an elongated projectile.

It has been stated that the retardation or rate at which a projectile loses velocity owing to the resistance of the air is given by

Effect of proportions of projectile.

$$\therefore f = K_v \times \frac{d^2}{w} \times \left(\frac{v}{1000}\right)^3 \ldots\ldots\ldots\ldots (1).$$

but as K is a coefficient depending only on the form and velocity of the projectile, it follows, for similarly shaped projectiles fired from guns of *different calibres* and moving with the same velocity, that

$$\text{the rate of loss of velocity varies simply as } \frac{d^2}{w};$$

or, if this statement is put in other words,

the power which a projectile has of *maintaining its velocity* varies as $\frac{w}{d^2}$ or $\frac{\text{weight of projectile}}{\text{square of its diameter}}$;

or the power of a projectile to maintain its velocity varies *directly as its weight, and inversely as the square of its diameter.*

With similarly shaped elongated projectiles the weight varies nearly as $d^2l$, where $l$ is the length of the projectile; consequently

$$\text{power of the projectile} \propto \frac{w}{d^2} \propto \frac{d^2l}{d^2} \propto l;$$

or the power of the projectile varies as its length.

Thus the longer the projectile (*cœteris paribus*) the harder will it hit at any given range, and the greater will be its absolute range for any given muzzle velocity; but other considerations limit the length of a projectile to about 3 calibres in service ordnance.

If elongated projectiles of similar shape were made the *same length in calibres*, it follows from what has been stated above that—

The power of the projectile varies as the calibre of the gun.

Influence of length of projectile.

As regards the length, this necessarily varies in the different descriptions of projectiles for the same gun, inasmuch as it is to some extent subordinate to the consideration of bringing them all (with certain exceptions) to the same weight. It has been decided that a length of two calibres at least is necessary for accurate shooting with our system of rifling,* and the length of the longest form of projectiles for Woolwich guns does not exceed three calibres, except in the case of double shell, which are peculiar to one heavy gun, *i.e.*, the 7-in., and are four calibres long. This extreme length entails in this case a low velocity and comparative inaccuracy.

Where however, the projectile is more accurately centred, the above statements require modification, as Sir W. Armstrong with his 6-inch gun has obtained very good results with a projectile only 1·84 diameters long, and on the other hand Herr Krupp uses successfully steel projectiles 4 calibres long.

Hollow projectiles.

The question of hollow shot in place of solid connects itself with this; indeed, a solid shot of two calibres long would in some cases exceed the desired weight for each gun, but besides the consideration of external form, the hollow shot, having its weight distributed further from its axis, has a slight advantage in having a longer radius of gyration and greater power of keeping up its rotation, though entailing a slightly increased strain on the gun.

### *Use of Tables and Examples.*

By means of equation (1) relations can be established between velocity and space, and also between velocity and time,† which will be true if the projectile be considered to move in a straight line.

Explanation of tables.

The results have been calculated by Professor Bashforth and tabulated in what may be called a *Distance and Velocity* Table (*vide* Table III., p. 135), and a *Time and Velocity* Table (*vide* Table IV., p. 139).

To provide for an extension of these tables to higher velocities, the force has been supposed to be *accelerating* instead of *retarding*, but this is of no moment, as the differences of the pairs of tabular numbers are alone made use of.

The mean difference of successive tabular numbers in each line has been given opposite that line.

The units employed are distance in feet, time in seconds, and velocity in feet seconds.

* Treatise on Ammunition, 1877, p. 183.

† *Vide* Bashforth's "Motion of Projectiles," p. 67; also Principles of Gunnery by Major Sladen.

Explanation of tables.

In Tables III. and IV. the left hand vertical column ($v$) denotes velocities from 400 to 2,500 f.s., at intervals of 10 f.s., and by means of the top horizontal column these velocities are subdivided into intervals of 1 f.s.

The figures in the vertical columns under 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 (Table III.), express the *distance in feet* corresponding to the velocities, and may be denoted by the abbreviation $S_V$ or $S_v$, the former being used to indicate that belonging to the higher of any pair of velocities.

For any pair of velocities V and $v$, the difference between the tabular numbers, corresponding to the velocities, or $S_V - S_v$, shows the distance in feet in which the velocity of a projectile *of unit weight and diameter* will be reduced from V to $v$.

Thus, if $V = 1600$ and $v = 601$, then

$$S_V - S_v = 23{,}606 \cdot 6 - 11{,}729 \cdot 5$$
$$= 11{,}877 \cdot 1.$$

That is the velocity will be reduced from 1,600 to 601 f.s. in 11,877·1 feet.

Similarly, the figures in the vertical columns under 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 (Table IV.), express the *time in seconds* corresponding to the velocities, and may be denoted by the abbreviation $T_V$ or $T_v$.

Application of tables.

The application to projectiles of different weights and diameters will now be considered, but in order to make use of Tables III. and IV., in the solution of problems in practical gunnery, it must be remembered that they apply *rigidly* only to elongated projectiles with ogival-shaped heads, of 1½ diameters and under conditions of atmosphere mentioned above, and that:—

V = the velocity of the projectile at the beginning of the distance or time under consideration,

$v$ = the velocity at the end of the distance or time under consideration,

$s$ = the distance or range in *feet*,

$t$ = the time in *seconds*,

$d$ = diameter of projectile in *inches*,

$w$ = weight of projectile in *lbs.*

With the above notation the equations used are, for distance and velocity

$$\frac{d^2}{w} s = S_V - S_v \text{.........................(I.)}$$

For time and velocity

$$\frac{d^2}{w} t = T_V - T_v \text{.......................(II.)}$$

Examples: (1.) EXAMPLE (1).—In what range would the velocity of a projectile fired from the 9-in. M.L. gun be reduced from 1420 f.s. to 1240 f.s.?

For the 9-in. shell, $d = 8\cdot 92$ in., $w = 250$ lbs.; also $V = 1420$, $v = 1240$.

Substituting in equation (I.),

$$\frac{d^2}{w}s = S_V - S_v;$$

$$\text{or } \frac{(8\cdot 92)^2}{250}s = S_{1420} - S_{1240} = 22789\cdot 3 - 21837\cdot 5, \text{ by Table III.}$$

$$\text{or } \cdot 3183\, s = 951\cdot 8 \text{ ft.};$$

$$\text{so that } s = 2990 \text{ ft.}$$

*i.e.*, the velocity would be reduced from 1420 f.s. to 1240 f.s. in about 2990 ft.

(2.) EXAMPLE (2).—In what *time* would the velocity of the same projectile be reduced from 1420 f.s. to 1240 f.s.?

Substituting in equation (II.),

$$\frac{d^2}{w}t = T_V - T_v;$$

$$\text{or } \frac{(8\cdot 92)^2}{250}t = T_{1420} - T_{1240} = 32\cdot 0569 - 31\cdot 3381, \text{ by Table IV.}$$

$$\text{or } \cdot 3183\, t = \cdot 7188 \text{ sec.};$$

$$\text{so that } t = 2\cdot 258 \text{ secs.},$$

*i.e.*, the velocity would be reduced from 1420 f.s. to 1240 f.s. in about $2\cdot 258$ secs.

(3.) EXAMPLE (3).—Find the remaining velocity of the 12·5-in. M.L. gun at 3000 ft.

In this case, $w = 800$ lbs., $d = 12\cdot 42$ ins., muzzle velocity $(V) = 1{,}420$ f.s., $s = 3000$ ft.

Substituting in equation (I.),

$$\frac{d^2}{w}s = S\ \ - S_v;$$

$$\text{or } \frac{(12\cdot 42)^2}{800} \times 3000 = S_{1420} - S_v$$

Transposing,

$$S_v = S_{1420} - \frac{(12\cdot 42)^2}{8} \times 30$$

$$= 22789\cdot 3 - 578\cdot 4 \text{ (since } S_{1420} = 22789\cdot 3 \text{ by Table III.)}$$

$$\text{or } S_v = 22210\cdot 9 \text{ ft.};$$

then from Table I. $v = 1305\cdot 8$ f.s.

*i.e.*, the remaining velocity at the distance of 3000 ft. from the muzzle is 1305·8 f.s.

EXAMPLE (4).—A shell fired from the 64-pr. M.L. gun with a charge of 10 lbs. of powder was observed to strike the crest of a parapet in 3 secs.; the muzzle velocity is known to be 1383 f.s. Find the striking velocity and the range. (4.)

In this case, $w = 64$ lbs., $d = 6{\cdot}22$ ins., $V = 1383$ f.s., $t = 3$ secs.

Substituting in equation (II.),

$$\frac{d^2}{w} t = T_V - T_v;$$

$$\text{or } \frac{(6{\cdot}22)^2}{64} \times 3 = T_{1383} - T_v;$$

$$\therefore T_v = T_{1383} - \frac{(6{\cdot}22)^2}{64} \times 3;$$

$$\text{or } = 31{\cdot}9282 - 1{\cdot}814 \text{ (since } T_{1383} = 31{\cdot}9282 \text{ by Table IV.)}$$

$$= 30{\cdot}1142 \text{ secs.}$$

Then from Table $v = 1049$ f.s.

*i.e.*, the striking velocity at the end of 3 secs. from firing = 1049 f.s.

Next, to find the range:—

Substituting in equation (I.),

$$\frac{d^2}{w} s = S_V - S_v;$$

$$\text{or } \frac{(6{\cdot}22)^2}{64} s = S_{1383} - S_{1049};$$

$$\text{or } {\cdot}6045 \; s = 22609{\cdot}1 \quad 20448{\cdot}7 \text{ (from Table III.,)}$$

$$\text{or } s = \frac{2160{\cdot}4}{{\cdot}6045} = 3576 \text{ ft.}$$

*i.e.*, the distance of the crest of the parapet from the gun is 3576 ft.

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## TRAJECTORIES.

The motion of a projectile in vacuo is given in ordinary works on dynamics, and will not be dealt with in this manual.

The method of determining the path in air has been indicated by Professor Bashforth in his "Motion of Projectiles," but the calculations are long and laborious. To obviate this a modification has been proposed by Mr. W. D. Niven, M.A. in his paper "On the calculation of the trajectories of shot" in

Bashforth's method.

the "Proceedings of the Royal Society," No. 181, 1877. This last solution is comparatively simple in application, and will be found explained in Major Sladen's "Principles of Gunnery," p. 72, from which the following is mainly taken.

### *Niven's Method.*

Niven's method.

Niven's method of solution depends upon the principle that a relation can be established between the velocity and the inclination of the trajectory at any given point of the path. These relations have been approximately determined and the results, as calculated by Mr. Niven, are given in what may be called an *Inclination and Velocity* table (Table V.), p. 143.

Explanation of table.

In this table the left hand vertical column ($v$) denotes velocities from 400 to 2500 f.s., at intervals of 10 f.s., and by means of the top horizontal column these velocities are subdivided into intervals of 1 f.s. The figures in the vertical columns under 0, 1, 2, 3, 4, &c. express quantities comparable with the *inclinations in degrees* of the tangent to the trajectory at points corresponding to the velocities, and may be denoted by the abbreviation $D_V$ or $D_v$, the former being used to indicate that belonging to the higher of any pair of velocities.

The connection between the number of degrees in the angle turned through by the direction of motion of the shot whilst the velocity changes from one value to another is expressed by equation (1) of the following page, but for the purpose of obtaining a preliminary idea of its meaning we shall suppose that the trajectory is very flat, the inclination being perhaps only a few, say 10, minutes. In that case the formula may be written

$$\frac{d^2}{w} D = D_V - D_v$$

and if the shot be of unit weight and unit diameter

$$D = D_V - D_v.$$

Thus, for a shot of this description fired at a very low inclination,

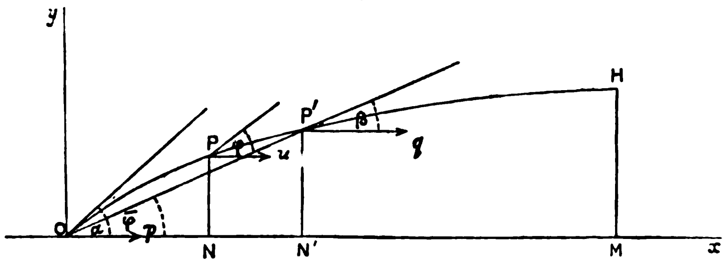
$$\text{if } V = 1600 \text{ and } v = 1569,$$
$$D = 84{\cdot}2778 - 84{\cdot}1779$$
$$= {\cdot}1 \text{ nearly.}$$

That is, the inclination of the shot will have diminished by 6′, whilst the velocity has changed from 1600 to 1569.

To make use of this table, it is necessary to divide the trajectory into arcs, and to determine the mean value of the inclination over each arc. This mean value is denoted by $\bar{\varphi}$.

The annexed figure will enable the following explanation to be more readily understood. Outline of calculation of trajectories.

Fig. 3.




In Fig. (3) let O be the point of projection;

$Ox$ and $Oy$ the horizontal and vertical lines in the plane of the trajectory;

H the vertex of the trajectory;

OP′ any arc of the trajectory;

$\alpha$ the inclination of the direction of motion at O to the horizontal line $Ox$.

$\beta$ the inclination at P′;

$p$ the horizontal component of the velocity at O;

$q$ the horizontal component of the velocity at P′;

$x$ the horizontal distance of P′ from O;

$y$ the vertical distance of P′ from O; and

T the time over the arc OP′.

Where the projectile is not of unit weight and diameter the values of the inclination and velocity given in Table V. are connected by the equation

$$\frac{d^2}{w} \mathrm{D} = \cos \bar{\varphi} \left( \mathrm{D}_{p \sec \bar{\phi}} - \mathrm{D}_{q \sec \bar{\phi}} \right) \dots\dots\dots (1).$$

Where $\mathrm{D} = \alpha - \beta$.

and $\mathrm{D}_{p \sec \phi}$, $\mathrm{D}_{q \sec \bar{\phi}}$ mean the values of D corresponding respectively to the velocities $p \sec \bar{\varphi}$ and $q \sec \bar{\varphi}$.

There is no means of determining the exact value of the mean angle $\bar{\varphi}$ in this case. As, however, $\sec \bar{\varphi}$ varies very slowly for the greater part of the trajectory, it will suffice in this equation to put $\bar{\varphi} = \frac{\alpha + \beta}{2}$ for low angles of elevation; but for high angles of elevation, $\bar{\varphi}$ should be more accurately determined from the formula

$$\tan \bar{\varphi} = \frac{\tan \alpha + \tan \beta}{2},$$

by means of a table of natural tangents.

Calculation of trajectories.

Using these approximate values of $\varphi$ and with the aid of Table V. the value of $q \sec \bar{\varphi}$ can be determined, and thence the value of $q$.

The steps in the calculation are—

$$\bar{\varphi}_1 = \frac{\alpha+\beta}{2} \text{ for low angles of elevation,}$$

$$\text{or } \tan \bar{\varphi}_1 = \frac{\tan \alpha + \tan \beta}{2} \text{ for high angles of elevation.}$$

where $\bar{\varphi}_1$ is a particular value of $\bar{\varphi}$.

If V is the muzzle velocity of the projectile, and $\alpha$ the angle of departure, then

$$p = \text{V} \cos \alpha, \text{ and } p \sec \bar{\varphi}_1 = \text{V} \cos \alpha \sec \bar{\varphi}_1 ;$$

then $q \sec \bar{\varphi}_1$ can be found from Table V. by equation (1) thus:

$$\text{D}_{q \sec \bar{\phi}_1} = \text{D}_{p \sec \bar{\phi}_1} - \frac{d^2}{w} \text{D} \sec \bar{\varphi}_1.$$

The values of X and Y are determined by means of Table III., p. 135, and the following equations:

$$\frac{d^2}{w}\text{X} = \cos \bar{\varphi}\,(\text{S}_{p \sec \bar{\phi}} - \text{S}_{q \sec \bar{\phi}}), \ldots\ldots\ldots\ldots\ldots (2)$$

$$\frac{d^2}{w}\text{Y} = \sin \bar{\varphi}\,(\text{S}_{p \sec \bar{\phi}} - \text{S}_{q \sec \bar{\phi}}) \ldots\ldots\ldots\ldots\ldots (3)$$

But the values of $\bar{\varphi}$ to be used are—

$$\bar{\phi} = \bar{\varphi}_1 + \tfrac{1}{8}\,\frac{p-q}{p+q}\,(\alpha-\beta)$$

for the ascending branch, and

$$\bar{\phi} = \bar{\varphi} - \tfrac{1}{3}\,\frac{p-q}{p+q}\,(\beta-\alpha)$$

for the descending branch.

The values of T can be determined by means of Table IV., p. 139, and the equation—

$$\frac{d^2}{w}\text{T} = (\text{T}_{p \sec \bar{\phi}'} - \text{T}_{q \sec \bar{\phi}'}) \ldots\ldots\ldots\ldots (4).$$

the more correct values of $\bar{\varphi}$ being

$$\bar{\varphi}' = \bar{\varphi}_1 + \tfrac{1}{6}\,\frac{p-q}{p+q}\,(\alpha-\beta)$$

in the ascending branch, and

$$\bar{\varphi}' = \bar{\varphi}_1 - \tfrac{1}{6}\,\frac{p-q}{p+q}\,(\beta-\alpha)$$

in the descending branch. Here $\bar{\varphi}'$ is a particular value of $\bar{\varphi}$, which is used when Table IV. is employed, but as the value of $\bar{\varphi}'$ does not occur outside the equation (4) the value $\bar{\varphi}_1$ may be taken and will give sufficiently accurate results.

This process will be repeated for each component arc in the ascending branch. A similar process is carried on for the descending branch; the sum of all the X's in the component arcs gives the range, and the sum of all the T's gives the time of flight.

### *Examples.*

**Example I.**—To find the trajectory, range, and time of flight of a 400 lb. shot fired with a muzzle velocity of 1700 *f. s.* the angle of departure being taken at 1°, and the diameter 9·92 inches. Example.

Here the angle of departure $\alpha = 1°$.

$$\frac{d^2}{w} = \frac{\overline{9\cdot92|}^2}{400} = \cdot246.$$

The whole ascending branch of the trajectory may be taken, and at the vertex

$$\beta = 0.$$

$$\text{Hence } D = \alpha - \beta = 1°.$$

In applying the formula for small angles of departure,—

$$D_{q \sec. \bar{\phi}} = D_{p \sec. \bar{\phi}} - \frac{d^2}{w} D \sec. \bar{\varphi}.$$

Sec. $\bar{\varphi}$ may be neglected and $p$ sec. $\bar{\varphi}$ may be taken equal to V the muzzle velocity, and $q$ sec. $\bar{\varphi} = v$ the remaining velocity at the end of the arc under consideration; so that the above formula becomes

$$D_v = D_V - \frac{d^2}{w} D = D_{1700} - \cdot246 \times 1$$

$$= 84\cdot5668 - \cdot246 = 84\cdot3208$$

$$\therefore v = 1614.$$

The formula for computing $\bar{\varphi}$ is in this case, where $\beta = 0$,

$$\bar{\varphi} = \frac{\alpha}{2} + \frac{p-q}{p+q} \cdot \frac{\alpha}{3}.$$

And since $p = V$, and $q = v$ nearly

$$\bar{\varphi} = 30' + \frac{1700 - 1614}{1700 + 1614} \times \frac{60}{3}$$

$$= 30' + \frac{86 \times 20}{3314} = 30'\cdot5.$$

Example.

The formula for computing X is

$$\frac{d^2}{w} X = \cos \bar{\varphi} \, (S_{p \sec. \bar{\phi}} - S_{q \sec. \bar{\phi}})$$

Which may be written in this case

$$\frac{d^2}{w} X = \cos \bar{\varphi} \, (S_V - S_v),$$

$$\text{or } X = \cos 30' \cdot 5 \times \frac{S_{1700} - S_{1614}}{\cdot 246}$$

$$= \cos 30' \cdot 5 \times \frac{24032 \cdot 7 - 23667 \cdot 3}{\cdot 246.}$$

$$= \frac{365 \cdot 4}{\cdot 246}$$

$$= 1485 \text{ feet.}$$

Maximum height.

Similarly,

$$Y = 1485 \times \sin 30' \cdot 5$$

$$= 13 \cdot 2 \text{ feet.}$$

Time of flight.

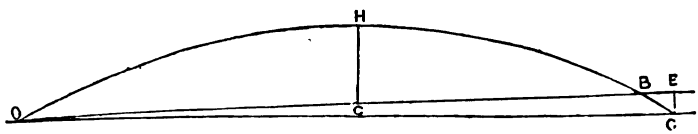
Similarly,

$$T = \frac{T_{1700} - T_{1614}}{\cdot 246}$$

$$\frac{3 \;\; \cdot 8580 - 32 \cdot 6373}{\cdot 246}$$

$$= \cdot 9 \text{ secs.}$$

Fig. 4.




To explain: the arc OH (where H is the vertex of the trajectory) has been computed, and

$$OC = X = 1485 \text{ ft.}$$
$$HC = Y = 13 \cdot 2 \text{ ft.}$$

or the height which the shot would have to fall from the vertex to reach a horizontal line through the muzzle of the gun. But if the range is measured to a lower level, $G$, the distance EG must be added to the height the shot has to fall —suppose in this case 10 ft.; then the height the shot has to fall from the vertex is $13 \cdot 2 + 10 = 23 \cdot 2$ ft.

Descending arch.

In computing the descending branch, it is necessary to decide upon some angle at the end of the arc and as near as

possible to the actual angle of descent. In this case compute the descending branch from 0° to 1° 12′. **Descending branch.**

Then, proceeding as before, since $D = 1° \; 12'$

$$D_v = D_V - \frac{d^2}{w} D = D_{1614} - \cdot 246 \times 1 \cdot 2$$

$$= 84 \cdot 3208 - \cdot 2952.$$
$$= 84 \cdot 0256.$$
$$v = 1525.$$

$$\text{and } \bar{\varphi}' = 36' - \frac{1614 - 1525}{1614 + 1525} \times \frac{72}{3}$$

$$= 36' - \frac{2136}{3139}$$

$$= 35' \; 20''$$

$$\text{Then } X' = \cos 35' \; 20'' \; \frac{S_{1614} - S_{1525}}{\cdot 246}$$

$$= \frac{23667 \cdot 3 - 23274 \cdot 8}{\cdot 246} \times \cos 35' \; 20''$$

$$= \frac{392 \cdot 5}{\cdot 246}$$

$$= 1596 \text{ ft.}$$

$$Y' = 1596 \times \sin 35' \; 20''$$
$$= 16 \cdot 4 \text{ ft.}$$

*i.e.*, there is yet $23 \cdot 2 - 16 \cdot 4 = 6 \cdot 8$ ft. to fall.

This gives one point to the descending branch, another can be found by taking D 1° 24′.

Then in this case

$$X'' = 1846$$
$$\text{and } Y'' = 22.$$

Having three points on the path, the trajectory can be determined with sufficient accuracy by plotting them on a suitable scale and then putting a curve through them.

The range can, however, be determined approximately by supposing the path after X′ Y′ to be a straight line.

Then taking $Y = 6{\cdot}8$.

$$X'' = 6{\cdot}8 \times \cot. 1° \; 12'.$$
$$= 334{\cdot}2 \text{ feet.}$$

| | | |
|---|---|---|
| Now X | = 1485 | „ |
| X′ | = 1596 | „ |
| X″ | = 324·2 | „ |

or total range = 3405 ft. = 1135 yds.

Again,—

$$T' = \frac{T_{1614} - T_{1525}}{\cdot 246}$$

$$= \frac{32 \cdot 6373 - 32 \cdot 3869}{\cdot 246} = \frac{\cdot 2504}{\cdot 246}$$

$$= 1 .017.$$

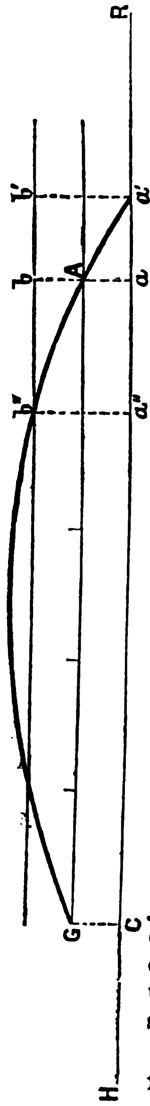



Fig. 5.

The little extra time taken to travel over $X'' = 324{\cdot}2$ feet may be approximated to by dividing the distance by the velocity at the end of the arc of $1^\circ\ 12'$ — *i.e.*, by $v' = 1525$; or

$$T'' = \frac{324{\cdot}2}{1525} = \cdot 21.$$

$$\text{Now } T = \cdot 9 \text{ sec.}$$
$$T' = 1 \cdot 017 \text{ sec.}$$
$$T'' = \cdot 21 \text{ sec.}$$
$$\therefore \text{ total time of flight} = 2 \cdot 13 \text{ sec.}$$

*Dangerous Space.*

Dangerous space.

The opposite diagram shows the trajectories calculated in this manner for the 10″ M.L.R. gun. It must be clearly understood that the *form* of the trajectory is not given, but only its height at particular distances. This is due to different scales being used for the vertical and horizontal. The dotted curve shows the gain due to an increased M.V.

The method of calculating a trajectory being understood the term "dangerous space" can be explained.

In Fig. 5 let G be the gun, 10 feet above the water H R, and laid for the centre A of an object *a b*, of which the height is 20 feet.

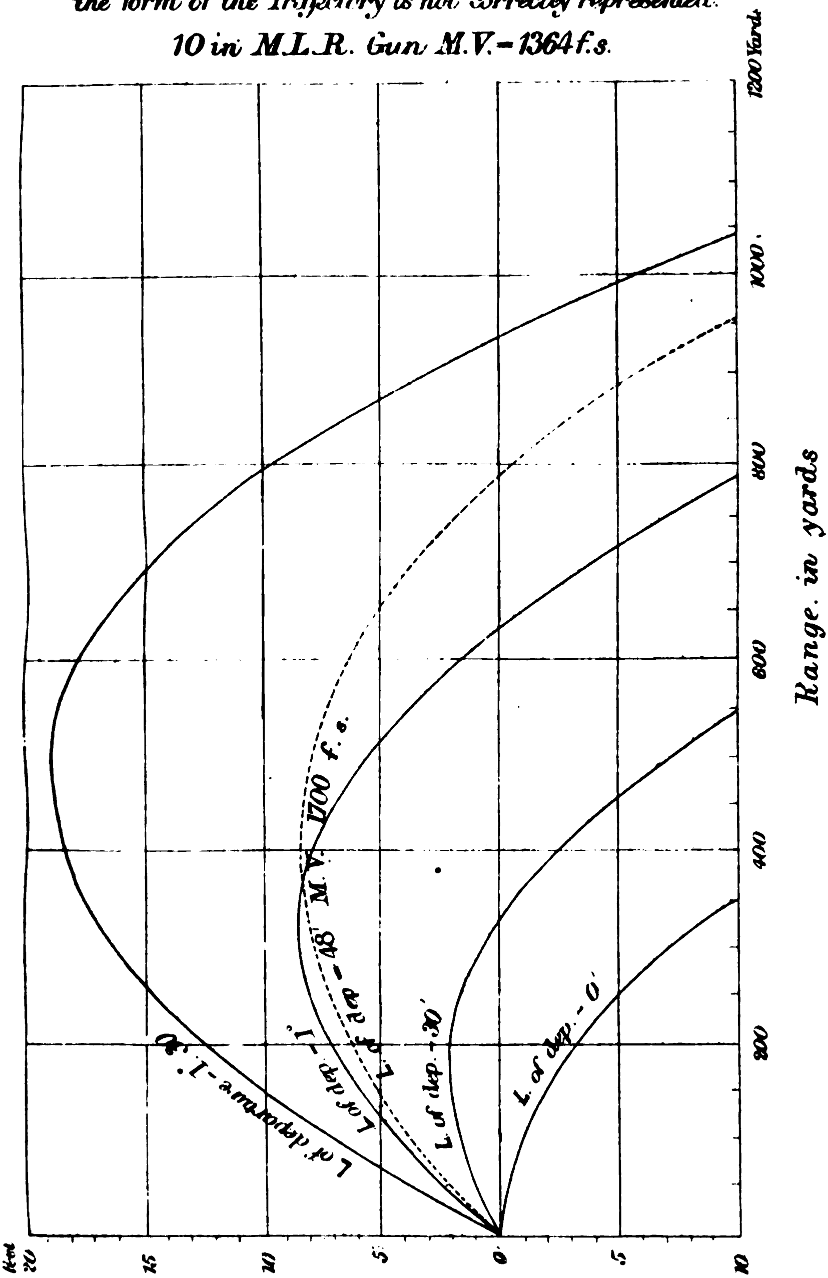
If the gun is elevated for the distance *a c*, the shot will strike the point A only if the object occupies the position *a b*. For any other position the shot will hit either higher or lower, it will just catch the top of the object when it is at *a″ b″*, and the bottom when at *a′ b′*. The space *a′ a″* is spoken of as the "dangerous space," as the object, if anywhere within it, will be hit somewhere.

The distances *ca″* and *ca′* have been calculated for a 9″·2 gun with various velocities, and the

## DIAGRAM.

*Showing the heights of Trajectory at various distances. The horizontal and vertical Scales not being the same, the form of the Trajectory is not correctly represented.*

*10 in. M.L.R. Gun M.V. = 1364 f.s.*




To face page 130

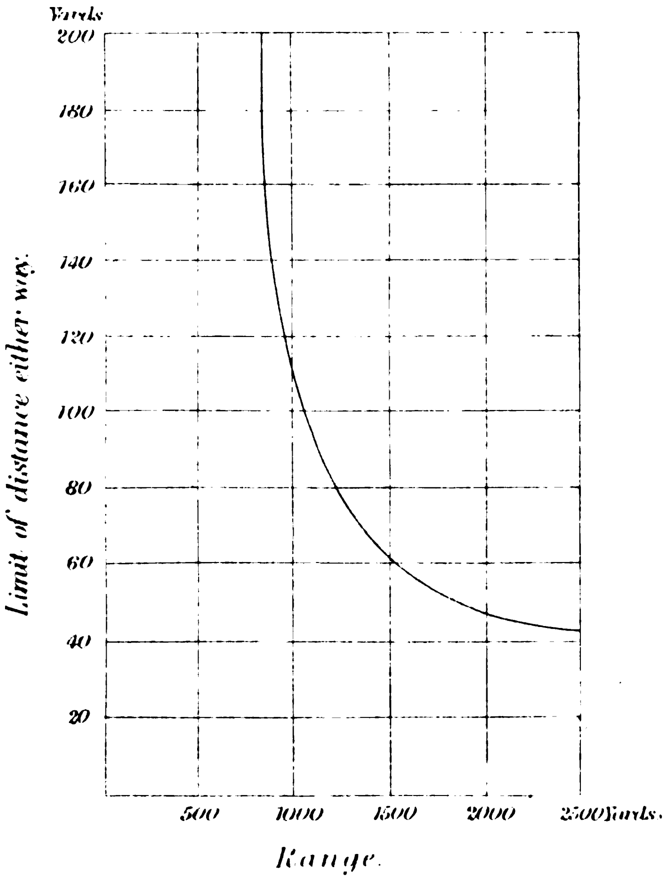


Dangerfield Lith. 22 Bedford St. Covent Garden

## DIAGRAM.

*Showing the limits within which the distance must be known in order to hit an object 20 feet high from a gun 10 feet above the plane.*

*Calculated for 10 in. M.L.R. Gun. M.V. - 1364 f.s.*




To face page 131



Danielsfield Lith 22 Bedford St Covent Garden

results are shown in the annexed table. The weight of the projectile is taken as 320 lbs., and the diameter 9″·15. **Dangerous space.**

| Range. | Muzzle Velocity. | | | | | |
|---|---|---|---|---|---|---|
| | 2,250. | | 1,900. | | 1,550. | |
| | ($ca''$) From. | ($ca'$) To. | ($ca''$) From. | ($ca'$) To. | ($ca''$) From. | ($ca'$) To. |
| | Yards. | Yards. | Yards. | Yards. | Yards. | Yards. |
| 600 | Muzzle | 870 | Muzzle. | 830 | Muzzle | 800 |
| 800 | „ | 1,040 | „ | 1,000 | 500 | 960 |
| 1,000 | „ | 1,230 | 650 | 1,170 | 830 | 1,120 |
| 1,200 | 820 | 1,400 | 990 | 1,345 | 1,075 | 1,295 |
| 1,400 | 1,155 | 1,580 | 1,235 | 1,525 | 1,300 | 1,480 |
| 1,600 | 1,405 | 1,755 | 1,465 | 1,710 | 1,515 | 1,670 |
| 2,000 | 1,865 | 2,120 | 1,895 | 2,085 | 1,935 | 2,05[illegible] |
| 2,400 | 2,295 | 2,490 | 2,320 | 2,465 | 2,350 | 2,4[illegible] |

The effect of the size of the gun on the length of the dangerous space is shown by a comparison of the 6″ B.L. and 9″·2 B.L. guns fired with the same muzzle velocity of 1,900 f.s.

| | | 6″ B.L. | 9″·2 B.L. |
|---|---|---|---|
| Range - | yards | 2,000 | 2,000 |
| Dangerous space - | from | 2,075 | 2,085 |
| „ | to | 1,920 | 1,895 |

In the annexed diagram, the distances $\frac{aa' + aa''}{2}$ have been taken as ordinates and the corresponding ranges as abscissæ, and the curve shows the rapidity with which this half dangerous space falls off as the range increases.

Thus, at a range of 1,000 yards, an error of distance of 110 yards would entail missing the object; while at 2,000 yards the distance must be known within about 44 yards.

It is recommended that in each ship the trajectories shall be calculated for the guns and charges carried.

For low angles of elevation the following approximate formulæ may be of use:—

**Angle of descent.**

$$\text{Tan. angle of descent} = \frac{g}{2} \times \frac{\text{total time of flight.}}{\text{hor. velocity on impact}}.$$

Also—

**Maximum height.**

$$\text{Max. height of trajectory} = \frac{g}{8} \times T^2$$

Where T = total time of flight.

## TABLE I.

### Co-efficients for the Cubic Law of the Resistance of the Air to Ogival-headed Shot.*

| $v.$ | $K_v.$ | $v.$ | $K_v.$ | $v.$ | $K_v.$ | $v.$ | $K_v.$ |
|---|---|---|---|---|---|---|---|
| f. s. | | f. s. | | f. s. | | f. s. | |
| 430 | 139·8 | 890 | 75·0 | 1350 | 107·1 | 1810 | 76·8 |
| 440 | 137·2 | 900 | 75·0 | 1360 | 106·7 | 1820 | 76·2 |
| 450 | 134·6 | 910 | 75·0 | 1370 | 106·3 | 1830 | 75·7 |
| 460 | 132·0 | 920 | 75·0 | 1380 | 105·8 | 1840 | 75·2 |
| 470 | 129·4 | 930 | 75·0 | 1390 | 105·3 | 1850 | 74·7 |
| 480 | 126·9 | 940 | 75·0 | 1400 | 104·7 | 1860 | 74·2 |
| 490 | 124·4 | 950 | 75·0 | 1410 | 104·1 | 1870 | 73·6 |
| 500 | 121·9 | 960 | 75·0 | 1420 | 103·5 | 1880 | 73·1 |
| 510 | 119·6 | 970 | 75·0 | 1430 | 102·9 | 1890 | 72·6 |
| 520 | 117·3 | 980 | 75·0 | 1440 | 102·3 | 1900 | 72·1 |
| 530 | 115·0 | 990 | 75·0 | 1450 | 101·6 | 1910 | 71·6 |
| 540 | 112·8 | 1000 | 75·0 | 1460 | 100·9 | 1920 | 71·2 |
| 550 | 110·7 | 1010 | 75·1 | 1470 | 100·1 | 1930 | 70·8 |
| 560 | 108·7 | 1020 | 75·3 | 1480 | 99·4 | 1940 | 70·4 |
| 570 | 106·7 | 1030 | 76·7 | 1490 | 98·6 | 1950 | 70·0 |
| 580 | 104·6 | 1040 | 80·8 | 1500 | 97·9 | 1960 | 69·7 |
| 590 | 102·5 | 1050 | 87·3 | 1510 | 97·1 | 1970 | 69·4 |
| 600 | 100·5 | 1060 | 94·0 | 1520 | 96·2 | 1980 | 69·2 |
| 610 | 98·6 | 1070 | 98·7 | 1530 | 95·3 | 1990 | 69·0 |
| 620 | 96·8 | 1080 | 102·2 | 1540 | 94·4 | 2000 | 68·8 |
| 630 | 95·1 | 1090 | 104·9 | 1550 | 93·6 | 2010 | 68·6 |
| 640 | 93·5 | 1100 | 106·9 | 1560 | 92·8 | 2020 | 68·4 |
| 650 | 91·9 | 1110 | 108·4 | 1570 | 92·0 | 2030 | 68·3 |
| 660 | 90·5 | 1120 | 109·2 | 1580 | 91·2 | 2040 | 68·2 |
| 670 | 89·1 | 1130 | 109·6 | 1590 | 90·4 | 2050 | 68·1 |
| 680 | 87·7 | 1140 | 109·6 | 1600 | 89·7 | 2060 | 68·0 |
| 690 | 86·3 | 1150 | 109·6 | 1610 | 89·0 | 2070 | 67·9 |
| 700 | 84·9 | 1160 | 109·6 | 1620 | 88·3 | 2080 | 67·9 |
| 710 | 83·7 | 1170 | 109·6 | 1630 | 87·6 | 2090 | 67·8 |
| 720 | 82·6 | 1180 | 109·6 | 1640 | 86·9 | 2100 | 67·8 |
| 730 | 81·6 | 1190 | 109·6 | 1650 | 86·2 | 2110 | 67·7 |
| 740 | 80·6 | 1200 | 109·6 | 1660 | 85·5 | 2120 | 67·6 |
| 750 | 79·6 | 1210 | 109·6 | 1670 | 84·8 | 2130 | 67·6 |
| 760 | 78·7 | 1220 | 109·6 | 1680 | 84·2 | 2140 | 67·5 |
| 770 | 78·0 | 1230 | 109·5 | 1690 | 83·6 | 2150 | 67·4 |
| 780 | 77·4 | 1240 | 109·5 | 1700 | 83·0 | 2160 | 67·3 |
| 790 | 76·8 | 1250 | 109·4 | 1710 | 82·4 | 2170 | 67·2 |
| 800 | 76·2 | 1260 | 109·3 | 1720 | 81·8 | 2180 | 67·2 |
| 810 | 75·6 | 1270 | 109·2 | 1730 | 81·2 | 2190 | 67·1 |
| 820 | 75·2 | 1280 | 109·0 | 1740 | 80·6 | 2200 | 67·0 |
| 830 | 75·1 | 1290 | 108·8 | 1750 | 80·0 | 2210 | 66·9 |
| 840 | 75·0 | 1300 | 108·6 | 1760 | 79·5 | 2220 | 66·8 |
| 850 | 75·0 | 1310 | 108·4 | 1770 | 78·9 | 2230 | 66·8 |
| 860 | 75·0 | 1320 | 108·1 | 1780 | 78·4 | 2240 | 66·7 |
| 870 | 75·0 | 1330 | 107·8 | 1790 | 77·8 | 2250 | 66·6 |
| 880 | 75·0 | 1340 | 107·5 | 1800 | 77·3 | | |

N.B.—In the above table a cubic foot of dry air is supposed to weigh 534·22 grs., which corresponds to the barometer at 30·0 ins. and thermometer at 62° F. The value of $K$ varies as the density of the air, but it is calculated at a standard density on the above supposition.

* Report of Experiments made with the Bashforth Chronograph, Part II. 1878–9.

## Table II.

**Showing the Resistance of the Air in pounds to Ogival-headed Shot, from one to twenty inches in Diameter, for specified Velocities.***

| v. | 1 in. | 2 in. | 3 in. | 4 in. | 5 in. | 6 in. | 7 in. | 8 in. | 9 in. | 10 in. | 11 in. | 12 in. | 13 in. | 14 in. | 15 in. | 16 in. | 17 in. | 18 in. | 19 in. | 20 in. | v. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f. s. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | f. s. |
| 450 | 0·381 | 1·5 | 3 | 6 | 10 | 14 | 19 | 24 | 31 | 38 | 46 | 55 | 64 | 75 | 86 | 98 | 110 | 123 | 138 | 152 | 450 |
| 500 | 0·473 | 1·9 | 4 | 8 | 12 | 17 | 23 | 30 | 38 | 47 | 57 | 68 | 80 | 93 | 106 | 121 | 137 | 153 | 171 | 189 | 500 |
| 550 | 0·572 | 2·3 | 5 | 9 | 14 | 20 | 28 | 36 | 46 | 57 | 69 | 82 | 97 | 112 | 129 | 146 | 165 | 185 | 206 | 229 | 550 |
| 600 | 0·674 | 2·7 | 6 | 11 | 17 | 24 | 33 | 43 | 55 | 67 | 82 | 97 | 114 | 132 | 152 | 173 | 195 | 218 | 243 | 270 | 600 |
| 650 | 0·784 | 3·1 | 7 | 13 | 20 | 28 | 38 | 50 | 64 | 78 | 95 | 113 | 132 | 154 | 176 | 203 | 227 | 254 | 288 | 314 | 650 |
| 700 | 0·905 | 3·6 | 8 | 14 | 23 | 33 | 44 | 58 | 73 | 91 | 110 | 130 | 153 | 177 | 204 | 232 | 262 | 203 | 327 | 362 | 700 |
| 750 | 1·043 | 4·2 | 9 | 17 | 26 | 38 | 51 | 67 | 84 | 104 | 126 | 150 | 176 | 204 | 235 | 267 | 801 | 338 | 377 | 417 | 750 |
| 800 | 1·212 | 4·8 | 11 | 19 | 30 | 44 | 59 | 78 | 98 | 121 | 147 | 176 | 205 | 238 | 273 | 310 | 350 | 393 | 438 | 485 | 800 |
| 850 | 1·430 | 5·7 | 13 | 23 | 36 | 51 | 70 | 92 | 116 | 143 | 173 | 206 | 242 | 280 | 322 | 366 | 418 | 463 | 516 | 572 | 850 |
| 900 | 1·698 | 6·8 | 15 | 27 | 42 | 61 | 83 | 109 | 138 | 170 | 205 | 245 | 287 | 833 | 382 | 435 | 491 | 550 | 613 | 679 | 900 |
| 950 | 1·997 | 8·0 | 19 | 32 | 50 | 72 | 98 | 128 | 162 | 200 | 242 | 288 | 337 | 391 | 449 | 511 | 577 | 647 | 721 | 799 | 950 |
| 1000 | 2·329 | 9·3 | 21 | 37 | 58 | 84 | 114 | 149 | 189 | 233 | 282 | 335 | 394 | 456 | 524 | 596 | 673 | 755 | 841 | 982 | 1000 |
| 1050 | 3·140 | 12·5 | 28 | 50 | 79 | 113 | 154 | 201 | 254 | 314 | 380 | 452 | 531 | 615 | 707 | 804 | 907 | 1 017 | 1,134 | 1,256 | 1050 |
| 1100 | 4·420 | 17·7 | 40 | 71 | 111 | 159 | 217 | 283 | 358 | 442 | 535 | 636 | 747 | 866 | 995 | 1,132 | 1,277 | 1,432 | 1,596 | 1,768 | 1100 |
| 1150 | 5·179 | 20·7 | 47 | 83 | 129 | 186 | 254 | 331 | 419 | 518 | 627 | 746 | 875 | 1,015 | 1,165 | 1,326 | 1,497 | 1,678 | 1,870 | 2,072 | 1150 |
| 1200 | 5·884 | 28·5 | 53 | 94 | 147 | 212 | 288 | 377 | 477 | 588 | 712 | 847 | 994 | 1,153 | 1,324 | 1,506 | 1,700 | 1,906 | 2,124 | 2,354 | 1200 |
| 1250 | 6·637 | 26·5 | 60 | 106 | 166 | 239 | 325 | 425 | 538 | 664 | 803 | 956 | 1,122 | 1,301 | 1,493 | 1,699 | 1,918 | 2,150 | 2,396 | 2,655 | 1250 |
| 1300 | 7·413 | 29·7 | 67 | 119 | 185 | 267 | 363 | 474 | 600 | 741 | 897 | 1,067 | 1,253 | 1,453 | 1,668 | 1,898 | 2,142 | 2,402 | 2,676 | 2,965 | 1300 |

* Report on Experiments made with the Bashforth Chronograph, Part II. 1878–9.

TABLE II.—*continued.*

Showing the Resistance of the Air in pounds to Ogival-headed Shot, from one to twenty inches in Diameter, for specified Velocities.

| *v.* | 1 in. | 2 in. | 3 in. | 4 in. | 5 in. | 6 in. | 7 in. | 8 in. | 9 in. | 10 in. | 11 in. | 12 in. | 13 in. | 14 in. | 15 in. | 16 in. | 17 in. | 18 in. | 19 in. | 20 in. | *v.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f. s. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | f. s. |
| 1350 | 8·186 | 32·7 | 74 | 131 | 205 | 295 | 401 | 524 | 663 | 819 | 991 | 1,179 | 1,383 | 1,604 | 1,842 | 2,096 | 2,366 | 2,652 | 2,955 | 3,274 | 1350 |
| 1400 | 8·924 | 35·7 | 80 | 143 | 223 | 321 | 437 | 571 | 723 | 892 | 1,080 | 1,285 | 1,508 | 1,749 | 2,008 | 2,285 | 2,579 | 2,891 | 3,222 | 3,570 | 1400 |
| 1450 | 9·621 | 38·5 | 87 | 154 | 241 | 346 | 471 | 616 | 779 | 962 | 1,164 | 1,385 | 1,626 | 1,886 | 2,165 | 2,463 | 2,780 | 3,117 | 3,473 | 3,848 | 1450 |
| 1500 | 10·263 | 41·1 | 92 | 164 | 257 | 369 | 503 | 657 | 831 | 1,026 | 1,242 | 1,478 | 1,734 | 2,012 | 2,309 | 2,627 | 2,966 | 3,325 | 3,705 | 4,105 | 1500 |
| 1550 | 10·829 | 43·3 | 97 | 173 | 271 | 390 | 531 | 693 | 877 | 1,083 | 1,310 | 1,559 | 1,830 | 2,122 | 2,437 | 2,772 | 3,130 | 3,509 | 3,909 | 4,332 | 1550 |
| 1600 | 11·416 | 45·7 | 103 | 183 | 285 | 411 | 559 | 731 | 925 | 1,142 | 1,381 | 1,644 | 1,929 | 2,238 | 2,569 | 2,922 | 3,299 | 3,699 | 4,121 | 4,566 | 1600 |
| 1650 | 12·030 | 48·1 | 108 | 192 | 301 | 433 | 589 | 770 | 974 | 1,203 | 1,456 | 1,732 | 2,033 | 2,358 | 2,707 | 3,080 | 3,477 | 3,898 | 4,343 | 4,812 | 1650 |
| 1700 | 12·666 | 50·7 | 114 | 203 | 317 | 456 | 621 | 811 | 1,026 | 1,267 | 1,533 | 1,824 | 2,141 | 2,483 | 2,850 | 3,242 | 3,660 | 4,104 | 4,572 | 5,066 | 1700 |
| 1750 | 13·318 | 53·3 | 120 | 213 | 333 | 479 | 653 | 852 | 1,079 | 1,332 | 1,611 | 1,918 | 2,251 | 2,610 | 2,997 | 3,409 | 3,849 | 4,315 | 4,808 | 5,327 | 1750 |
| 1800 | 14·003 | 56·0 | 126 | 224 | 350 | 504 | 686 | 896 | 1,134 | 1,400 | 1,694 | 2,016 | 2,367 | 2,745 | 3,151 | 3,585 | 4,047 | 4,537 | 5,055 | 5,601 | 1800 |
| 1850 | 14·689 | 58·8 | 132 | 235 | 367 | 529 | 720 | 940 | 1,190 | 1,469 | 1,777 | 2,115 | 2,482 | 2,879 | 3,305 | 3,760 | 4,245 | 4,759 | 5,303 | 5,876 | 1850 |
| 1900 | 15·364 | 61·5 | 138 | 246 | 384 | 553 | 753 | 983 | 1,244 | 1,536 | 1,859 | 2,212 | 2,597 | 3,011 | 3,457 | 3,933 | 4,440 | 4,978 | 5,546 | 6,146 | 1900 |
| 1950 | 16·127 | 64·5 | 145 | 258 | 403 | 581 | 790 | 1,032 | 1,306 | 1,613 | 1,951 | 2,322 | 2,725 | 3,161 | 3,629 | 4,129 | 4,661 | 5,225 | 5,822 | 6,451 | 1950 |
| 2000 | 17·096 | 68·4 | 154 | 274 | 427 | 615 | 838 | 1,093 | 1,385 | 1,710 | 2,069 | 2,462 | 2,889 | 3,351 | 3,847 | 4,377 | 4,941 | 5,539 | 6,172 | 6,838 | 2000 |
| 2050 | 18·230 | 72·9 | 164 | 292 | 456 | 656 | 893 | 1,167 | 1,477 | 1,823 | 2,206 | 2,625 | 3,081 | 3,573 | 4,102 | 4,667 | 5,268 | 5,907 | 6,581 | 7,292 | 2050 |
| 2100 | 19·504 | 78·0 | 176 | 312 | 488 | 702 | 956 | 1,248 | 1,580 | 1,950 | 2,360 | 2,809 | 3,296 | 3,823 | 4,388 | 4,993 | 5,637 | 6,319 | 7,041 | 7,802 | 2100 |
| 2150 | 20·811 | 83·2 | 187 | 333 | 520 | 749 | 1,020 | 1,332 | 1,686 | 2,081 | 2,518 | 2,997 | 3,517 | 4,079 | 4,682 | 5,328 | 6,014 | 6,743 | 7,513 | 8,324 | 2150 |
| 2200 | 22·159 | 88·6 | 199 | 355 | 554 | 798 | 1,086 | 1,418 | 1,795 | 2,216 | 2,681 | 3,191 | 3,745 | 4,343 | 4,986 | 5,673 | 6,404 | 7,180 | 7,999 | 8,864 | 2200 |
| 2250 | 23·567 | 94·3 | 212 | 377 | 589 | 848 | 1,155 | 1,508 | 1,909 | 2,357 | 2,852 | 3,393 | 3,983 | 4,619 | 5,303 | 6,033 | 6,811 | 7,636 | 8,508 | 9,427 | 2250 |

## Table III.

### Distance and Velocity Table. $\frac{d^2}{w} s = S - S_v$.*

| *v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | |
| 40 | 5000·0 | 5042·1 | 5084·1 | 5125·9 | 5167·7 | 5209·3 | 5250·8 | 5292·2 | 5333·5 | 5374·7 | 41·6 |
| 41 | 5415·7 | 5456·7 | 5497·5 | 5538·2 | 5578·8 | 5619 3 | 5659·6 | 5699·9 | 5740·0 | 5780·0 | 40·4 |
| 42 | 5819·9 | 5859·7 | 5899·4 | 5938·9 | 5978·4 | 6017·7 | 6057·0 | 6096·1 | 6135·1 | 6174·0 | 39·3 |
| 43 | 6212·8 | 6251·5 | 6290·1 | 6328·6 | 6367·0 | 6405·2 | 6443·4 | 6481·5 | 6519·4 | 6557·3 | 38·2 |
| 44 | 6595·0 | 6632·7 | 6670·2 | 6707·7 | 6745·0 | 6782·3 | 6819·5 | 6856·5 | 6893·5 | 6930·4 | 37·2 |
| 45 | 6967·2 | 7003·9 | 7040·5 | 7077·0 | 7113·4 | 7149·7 | 7186·0 | 7222·1 | 7258·2 | 7294·2 | 36·3 |
| 46 | 7330·1 | 7365·9 | 7401·6 | 7437·2 | 7472·8 | 7508·2 | 7543·6 | 7578·9 | 7614·2 | 7649·3 | 35·4 |
| 47 | 7684·4 | 7719·3 | 7754·2 | 7789·1 | 7823·8 | 7858·5 | 7893·1 | 7927·6 | 7962·0 | 7996·4 | 34·6 |
| 48 | 8030·7 | 8064·9 | 8099·0 | 8133·1 | 8167·1 | 8201·0 | 8234·8 | 8268·6 | 8302·3 | 8335·9 | 33·9 |
| 49 | 8369·5 | 8403·0 | 8436·4 | 8469·7 | 8503·0 | 8536·2 | 8569·4 | 8602·4 | 8635·5 | 8668·4 | 33·2 |
| 50 | 8701·3 | 8734·1 | 8766·8 | 8799·5 | 8832·1 | 8864·7 | 8897·2 | 8929·6 | 8961·9 | 8994.2 | 32·5 |
| 51 | 9026·4 | 9058·6 | 9090·7 | 9122·7 | 9154·7 | 9186·6 | 9218·4 | 9250·2 | 9281·9 | 9313·6 | 31·9 |
| 52 | 9345·2 | 9376·7 | 9408·2 | 9439·6 | 9471·0 | 9502·3 | 9533·5 | 9564·7 | 9595·8 | 9626·9 | 31·3 |
| 53 | 9657·9 | 9688·9 | 9719·8 | 9750·6 | 9781·4 | 9812·1 | 9842·8 | 9873·4 | 9904·0 | 9934·5 | 30·7 |
| 54 | 9965·0 | 9995·4 | 0025·7 | 0056·0 | 0086·3 | 0116·4 | 0146·6 | 0176·7 | 0206·7 | 0236·6 | 30·2 |
| 55 | 10266·6 | 0296·4 | 0326·2 | 0356·0 | 0385·7 | 0415·4 | 0445·0 | 0474·5 | 0504·0 | 0533·4 | 29·6 |
| 56 | 10562·8 | 0592·2 | 0621·5 | 0650·7 | 0679·9 | 0709·1 | 0738·2 | 0767·2 | 0796·2 | 0825·2 | 29·1 |
| 57 | 10854·1 | 0883·0 | 0911·8 | 0940·6 | 0969·3 | 0998·0 | 1026·7 | 1055·3 | 1083·8 | 1112·4 | 28·7 |
| 58 | 11140·8 | 1169·2 | 1197·6 | 1226·0 | 1254·3 | 1282·5 | 1310·8 | 1339·0 | 1367·1 | 1395·2 | 28·3 |
| 59 | 11423·3 | 1451·3 | 1479·3 | 1507·3 | 1535·2 | 1563·0 | 1590·9 | 1618·7 | 1646·4 | 1674·2 | 27·9 |
| 60 | 11701·8 | 1729·5 | 1757·1 | 1784·6 | 1812·2 | 1839·6 | 1867·1 | 1894·5 | 1921·9 | 1949·2 | 27·5 |
| 61 | 11976·5 | 2003·7 | 2031·0 | 2058·1 | 2085·3 | 2112·4 | 2139·4 | 2166·4 | 2193·4 | 2220·4 | 27·1 |
| 62 | 12247·3 | 2274·2 | 2301·0 | 2327·8 | 2354·6 | 2381·3 | 2407·9 | 2434·6 | 2461·2 | 2487·7 | 26·7 |
| 63 | 12514·3 | 2540·8 | 2567·2 | 2593·6 | 2620·0 | 2646·3 | 2672·6 | 2698·9 | 2725·1 | 2751·3 | 26·3 |
| 64 | 12777·5 | 2803·6 | 2829·7 | 2855·7 | 2881·7 | 2907·7 | 2933·7 | 2959·6 | 2985·4 | 3011·2 | 26·0 |
| 65 | 13037·0 | 3062·8 | 3088·5 | 3114·2 | 3139·8 | 3165·4 | 3191·0 | 3216·5 | 3242 0 | 3267·4 | 25·6 |
| 66 | 13292·8 | 3318·2 | 3343·5 | 3368·8 | 3394·1 | 3419·3 | 3444·5 | 3469·6 | 3494·7 | 3519·8 | 25·2 |
| 67 | 13544·8 | 3569·8 | 3594·8 | 3619·8 | 3644·7 | 3669·5 | 3694·3 | 3719·1 | 3743·9 | 3768·6 | 24·8 |
| 68 | 13793·3 | 3818·0 | 3842·6 | 3867·2 | 3891·7 | 3916·2 | 3940·7 | 3965·2 | 3989·6 | 4014·0 | 24·5 |
| 69 | 14038·4 | 4062·7 | 4087·0 | 4111·3 | 4135·6 | 4159·8 | 4184·0 | 4208·1 | 4232·2 | 4256·3 | 24·2 |
| 70 | 14280·4 | 4304·5 | 4328·5 | 4352·4 | 4376·4 | 4400·3 | 4424·1 | 4448·0 | 4471·8 | 4495·5 | 23·9 |
| 71 | 14519·3 | 4543·0 | 4566·6 | 4590·2 | 4613·8 | 4637·4 | 4660·9 | 4684·4 | 4707·8 | 4731·3 | 23·5 |
| 72 | 14754·7 | 4777·9 | 4801·3 | 4824·6 | 4847·9 | 4871·1 | 4894·2 | 4917·4 | 4940·5 | 4963·6 | 23·2 |
| 73 | 14986·6 | 5009·6 | 5032·6 | 5055·5 | 5078·4 | 5101·3 | 5124·1 | 5146·9 | 5169·6 | 5192·4 | 22·8 |
| 74 | 15215·1 | 5237·7 | 5260·3 | 5282·9 | 5305·5 | 5328·0 | 5350·5 | 5373·0 | 5395·4 | 5417·8 | 22·5 |
| 75 | 15440·2 | 5462·5 | 5484·8 | 5507·1 | 5529·3 | 5551·5 | 5573·7 | 5595·8 | 5617·9 | 5640·0 | 22·2 |
| 76 | 15662·1 | 5684·1 | 5706·0 | 5728·0 | 5749·9 | 5771·7 | 5793·5 | 5815·3 | 5837·0 | 5858·7 | 21·8 |
| 77 | 15880·4 | 5902·0 | 5923·6 | 5945·1 | 5966·6 | 5988·1 | 6009·5 | 6030·9 | 6052·2 | 6073·6 | 21·5 |
| 78 | 16094·8 | 6116·1 | 6137·3 | 6158·4 | 6179·6 | 6200·7 | 6221·7 | 6242·7 | 6263·7 | 6284·6 | 21·1 |
| 79 | 16305·5 | 6326·4 | 6347·2 | 6368·0 | 6388·4 | 6409·5 | 6430·2 | 6450·8 | 6471·4 | 6492·0 | 20·7 |
| 80 | 16512·6 | 6533·1 | 6553·6 | 6574·0 | 6594·4 | 6614·8 | 6635·1 | 6655·4 | 6675·7 | 6695·9 | 20·4 |
| 81 | 16716·1 | 6736·3 | 6756·4 | 6776·5 | 6796·5 | 6816·5 | 6836·5 | 6856·4 | 6876·3 | 6896·1 | 20·0 |
| 82 | 16916·0 | 6935·7 | 6955·5 | 6975·1 | 6994·8 | 7014·4 | 7033·9 | 7053·4 | 7072·9 | 7092·3 | 19·6 |
| 83 | 17111·7 | 7131·0 | 7150·3 | 7169·6 | 7188·8 | 7207·9 | 7227·1 | 7246·1 | 7265·2 | 7284·1 | 19·1 |
| 84 | 17303·1 | 7322·0 | 7340·8 | 7359·6 | 7378·4 | 7397·1 | 7415·8 | 7434·4 | 7453·0 | 7471·5 | 18·7 |
| 85 | 17490·0 | 7508·5 | 7526·9 | 7545·3 | 7563·6 | 7581·8 | 7600·0 | 7618·2 | 7636·3 | 7654·4 | 18·2 |
| 86 | 17672·4 | 7690·5 | 7708·4 | 7726·4 | 7744·2 | 7762·0 | 7779·9 | 7797·6 | 7815·4 | 7833·0 | 17·8 |
| 87 | 17850·6 | 7868·2 | 7885·8 | 7903·3 | 7920·8 | 7938·2 | 7955·6 | 7973·0 | 7990·3 | 8007·6 | 17·4 |
| 88 | 18024·8 | 8042·0 | 8059·2 | 8076·3 | 8093·4 | 8110·4 | 8127·4 | 8144·4 | 8161·3 | 8178·2 | 17·0 |
| 89 | 18195·0 | 8211·9 | 8228·6 | 8245·4 | 8262·1 | 8278·7 | 8295·4 | 8312·0 | 8328·5 | 8345·0 | 16·6 |
| 90 | 18361·5 | 8377·9 | 8394·3 | 8410·7 | 8427·0 | 8443·3 | 8459·6 | 8475·8 | 8492·0 | 8508·2 | 16·3 |

* Report of Experiments made with the Bashforth Chronograph, Part II. 1878–9.

## TABLE III. $\frac{d}{w}s = S_V - S_v$—(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | |
| 91 | 18524·3 | 8540·4 | 8556·4 | 8572·4 | 8588·4 | 8604·3 | 8620·3 | 8636·1 | 8652·0 | 8667·8 | 15·9 |
| 92 | 18683·5 | 8699·3 | 8715·0 | 8730·7 | 8746·3 | 8761·9 | 8777·5 | 8793·0 | 8808·5 | 8824·0 | 15·6 |
| 93 | 18839·4 | 8854·8 | 8870·2 | 8885·5 | 8900·8 | 8916·1 | 8931·3 | 8946·5 | 8961·7 | 8976·8 | 15·3 |
| 94 | 18991·9 | 9007·0 | 9022·0 | 9037·0 | 9052·0 | 9066·9 | 9081·9 | 9096·7 | 9111·6 | 9126·4 | 15·0 |
| 95 | 19141·2 | 9156·0 | 9170·7 | 9185·4 | 9200·1 | 9214·7 | 9229·3 | 9243·9 | 9258·4 | 9272·9 | 14·6 |
| 96 | 19287·4 | 9301·9 | 9316·3 | 9330·7 | 9345·0 | 9359·4 | 9373·7 | 9387·9 | 9402·2 | 9416·4 | 14·3 |
| 97 | 19430·6 | 9444·7 | 9458·9 | 9473·0 | 9487·0 | 9501·1 | 9515·1 | 9529·1 | 9543·0 | 9557·0 | 14·0 |
| 98 | 19570·8 | 9584·7 | 9598·6 | 9612·4 | 9626·1 | 9639·9 | 9653·6 | 9667·3 | 9681·0 | 9694·6 | 13·7 |
| 99 | 19708·3 | 9721·9 | 9735·4 | 9749·0 | 9762·5 | 9775·9 | 9789·4 | 9802·8 | 9816·2 | 9829·6 | 13·5 |
| 100 | 19842·9 | 9856·3 | 9869·6 | 9882·9 | 9896·1 | 9909·3 | 9922·5 | 9935·7 | 9948·8 | 9961·6 | 13·2 |
| 101 | 19975·0 | 9988·1 | 0001·1 | 0014·1 | 0027·1 | 0040·0 | 0052·9 | 0065·8 | 0078·7 | 0091·5 | 12·9 |
| 102 | 20104·3 | 0117·1 | 0129·8 | 0142·5 | 0155·2 | 0167·8 | 0180·4 | 0192·9 | 0205·4 | 0217·8 | 12·6 |
| 103 | 20230·1 | 0242·4 | 0254·6 | 0266·8 | 0278·8 | 0290·8 | 0302·7 | 0314·5 | 0326·2 | 0337·8 | 11·9 |
| 104 | 20349·4 | 0360·8 | 0372·2 | 0383·4 | 0394·5 | 0405·6 | 0416·5 | 0427·3 | 0438·1 | 0448·7 | 11·0 |
| 105 | 20459·2 | 0469·6 | 0479·9 | 0490·0 | 0500·1 | 0510·1 | 0520·0 | 0529·8 | 0539·5 | 0549·2 | 9·9 |
| 106 | 20558·7 | 0568·2 | 0577·6 | 0586·9 | 0596·2 | 0605·4 | 0614·5 | 0623·6 | 0632·6 | 0641·6 | 9·2 |
| 107 | 20650·5 | 0659·3 | 0668·1 | 0676·9 | 0685·6 | 0694·2 | 0702·8 | 0711·4 | 0719·9 | 0728·4 | 8·6 |
| 108 | 20736·8 | 0745·2 | 0753·6 | 0761·9 | 0770·2 | 0778·4 | 0786·6 | 0794·8 | 0802·9 | 0811·0 | 8·2 |
| 109 | 20819·0 | 0827·1 | 0835·0 | 0843·0 | 0850·9 | 0858·9 | 0866·7 | 0874·6 | 0882·4 | 0890·2 | 7·9 |
| 110 | 20897·9 | 0905·7 | 0913·4 | 0921·1 | 0928·7 | 0936·4 | 0944·0 | 0951·5 | 0959·1 | 0966·6 | 7·6 |
| 111 | 20974·2 | 0981·6 | 0989·1 | 0996·6 | 1004·0 | 1011·4 | 1018·8 | 1026·2 | 1033·5 | 1040·9 | 7·4 |
| 112 | 21048·2 | 1055·5 | 1062·8 | 1070·0 | 1077·3 | 1084·5 | 1091·7 | 1099·0 | 1106·1 | 1113·3 | 7·2 |
| 113 | 21120·5 | 1127·6 | 1134·8 | 1141·9 | 1149·0 | 1156·1 | 1163·2 | 1170·2 | 1177·3 | 1184·4 | 7·1 |
| 114 | 21191·4 | 1198·4 | 1205·4 | 1212·4 | 1219·4 | 1226·4 | 1233·3 | 1240·3 | 1247·2 | 1254·1 | 7·0 |
| 115 | 21261·0 | 1267·9 | 1274·8 | 1281·7 | 1288·6 | 1295·4 | 1302·3 | 1309·1 | 1315·9 | 1322·7 | 6·8 |
| 116 | 21329·5 | 1336·3 | 1343·1 | 1349·8 | 1356·6 | 1363·3 | 1370·0 | 1376·7 | 1383·4 | 1390·1 | 6·7 |
| 117 | 21396·8 | 1403·5 | 1410·1 | 1416·8 | 1423·4 | 1430·0 | 1436·6 | 1443·2 | 1449·8 | 1456·4 | 6·6 |
| 118 | 21462·9 | 1469·5 | 1476·0 | 1482·6 | 1489·1 | 1495·6 | 1502·1 | 1508·6 | 1515·1 | 1521·5 | 6·5 |
| 119 | 21528·0 | 1534·4 | 1540·9 | 1547·3 | 1553·7 | 1560·1 | 1566·5 | 1572·9 | 1579·2 | 1585·6 | 6·4 |
| 120 | 21591·9 | 1598·3 | 1604·6 | 1610·9 | 1617·2 | 1623·5 | 1629·8 | 1636·1 | 1642·3 | 1648·6 | 6·3 |
| 121 | 21654·8 | 1661·1 | 1667·3 | 1673·5 | 1679·7 | 1685·9 | 1692·1 | 1698·2 | 1704·4 | 1710·5 | 6·2 |
| 122 | 21716·7 | 1722·8 | 1728·9 | 1735·0 | 1741·1 | 1747·2 | 1753·3 | 1759·4 | 1765·4 | 1771·7 | 6·1 |
| 123 | 21777·5 | 1783·6 | 1789·6 | 1795·6 | 1801·6 | 1807·6 | 1813·6 | 1819·6 | 1825·6 | 1831·5 | 6·0 |
| 124 | 21837·5 | 1843·4 | 1849·4 | 1855·3 | 1861·2 | 1867·1 | 1873·0 | 1878·9 | 1884·8 | 1890·6 | 5·9 |
| 125 | 21896·5 | 1902·3 | 1908·2 | 1914·0 | 1919·8 | 1925·6 | 1931·5 | 1937·3 | 1943·0 | 1948·8 | 5·8 |
| 126 | 21954·6 | 1960·4 | 1966·1 | 1971·9 | 1977·6 | 1983·3 | 1989·0 | 1994·8 | 2000·5 | 2006·2 | 5·7 |
| 127 | 22011·8 | 2017·5 | 2023·2 | 2028.9 | 2034·5 | 2040·2 | 2045·8 | 2051·4 | 2057·0 | 2062·7 | 5·6 |
| 128 | 22068·3 | 2073·9 | 2079·5 | 2085·0 | 2090·6 | 2096·2 | 2101·8 | 2107·3 | 2112·9 | 2118·4 | 5·6 |
| 129 | 22123·9 | 2129·4 | 2135·0 | 2140·5 | 2146·0 | 2151·5 | 2157·0 | 2162·4 | 2167·9 | 2173·4 | 5·5 |
| 130 | 22178·8 | 2184·3 | 2189·7 | 2195·1 | 2200·6 | 2206·0 | 2211·4 | 2216·8 | 2222·2 | 2227·6 | 5·4 |
| 131 | 22233·0 | 2238·4 | 2243·7 | 2249·1 | 2254·5 | 2259·8 | 2265·1 | 2270·5 | 2275·8 | 2281·1 | 5·3 |
| 132 | 22286·4 | 2291·8 | 2297·1 | 2302·4 | 2307·6 | 2312·9 | 2318·2 | 2323·5 | 2328·7 | 2334·0 | 5·3 |
| 133 | 22339·2 | 2344·5 | 2349·7 | 2355·0 | 2360·2 | 2365·4 | 2370·6 | 2375·8 | 2381·0 | 2381·2 | 5·2 |
| 134 | 22391·4 | 2396·6 | 2401·8 | 2406·9 | 2412·1 | 2417·3 | 2422·4 | 2427·6 | 2432·7 | 2437·8 | 5·2 |
| 135 | 22443·0 | 2448·1 | 2453·2 | 2458·3 | 2463·4 | 2468·5 | 2473·6 | 2478·7 | 2483·8 | 2488·9 | 5·1 |
| 136 | 22493·9 | 2499·0 | 2504·1 | 2509·1 | 2514·2 | 2519·2 | 2524·3 | 2529·3 | 2534·3 | 2539·4 | 5·0 |
| 137 | 22544·4 | 2549·4 | 2564·4 | 2559·4 | 2564·4 | 2569·4 | 2574·4 | 2579·4 | 2584·3 | 2589·3 | 5·0 |
| 138 | 22594·3 | 2599·2 | 2604·2 | 2609·1 | 2614·1 | 2619·0 | 2624·0 | 2628·9 | 2633·8 | 2638·8 | 4·9 |
| 139 | 22643·7 | 2648·6 | 2653·5 | 2658·4 | 2663·3 | 2668·2 | 2673·1 | 2678·0 | 2682·9 | 2687·8 | 4·9 |
| 140 | 22692·6 | 2697·5 | 2702·4 | 2707·2 | 2712·1 | 2717·0 | 2721·8 | 2726·7 | 2731·5 | 2736·9 | 4·9 |
| 141 | 22741·2 | 2746·0 | 2750·8 | 2755·7 | 2760·5 | 2765·3 | 2770·1 | 2774·9 | 2779·7 | 2784·5 | 4·8 |
| 142 | 22789·3 | 2794·1 | 2798·9 | 2803·7 | 2808·5 | 2813·2 | 2818·0 | 2822·8 | 2827·5 | 2832·3 | 4·8 |
| 143 | 22837·1 | 2841·8 | 2846·6 | 2851·3 | 2856·0 | 2860·8 | 2865·5 | 2870·2 | 2875·0 | 2879·7 | 4·7 |
| 144 | 22884·4 | 2889·1 | 2893·8 | 2898·6 | 2903·3 | 2908·0 | 2912·7 | 2917·4 | 2922·1 | 2926·7 | 4·7 |

TABLE III. $\frac{d^2}{w}s = S_V - S_v$—(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | |
| 145 | 22931·4 | 2936·1 | 2940·8 | 2945·5 | 2950·1 | 2954·8 | 2959·5 | 2964·1 | 2968·8 | 2973·5 | 4·7 |
| 146 | 22978·1 | 2982·8 | 2987·4 | 2992·1 | 2996·7 | 3001·3 | 3006·0 | 3010·6 | 3015·2 | 3019·9 | 4·6 |
| 147 | 23024·5 | 3029·1 | 3033·7 | 3038·4 | 3043·0 | 3047·6 | 3052·2 | 3056·8 | 3061·4 | 3066·0 | 4·6 |
| 148 | 23070·6 | 3075·2 | 3079·8 | 3084·4 | 3089·0 | 3093·5 | 3098·1 | 3102·7 | 3107·3 | 3111·8 | 4·6 |
| 149 | 23116·4 | 3121·0 | 3125·6 | 3130·1 | 3134·7 | 3139·2 | 3143·8 | 3148·3 | 3152·9 | 3157·4 | 4·6 |
| 150 | 23162·0 | 3166·5 | 3171·0 | 3175·6 | 3180·1 | 3184·6 | 3189·2 | 3193·7 | 3198·2 | 3202·7 | 4·5 |
| 151 | 23207·2 | 3211·8 | 3216·3 | 3220·8 | 3225·3 | 3229·8 | 3234·3 | 3238·8 | 3243·3 | 3247·8 | 4·5 |
| 152 | 23252·3 | 3256·8 | 3261·3 | 3265·8 | 3270·3 | 3274·8 | 3279·3 | 3283·8 | 3288·3 | 3292·8 | 4·5 |
| 153 | 23297·2 | 3301·7 | 3306·2 | 3310·6 | 3315·1 | 3319·6 | 3324·1 | 3328·5 | 3333·0 | 3337·5 | 4·5 |
| 154 | 23342·0 | 3346·4 | 3350·9 | 3355·3 | 3359·8 | 3364·3 | 3368·7 | 3373·2 | 3377·6 | 3382·1 | 4·5 |
| 155 | 23386·5 | 3391·0 | 3395·4 | 3399·9 | 3404·3 | 3408·7 | 3413·2 | 3417·6 | 3422·0 | 3426·5 | 4·4 |
| 156 | 23430·9 | 3435·3 | 3439·8 | 3444·2 | 3448·6 | 3453·0 | 3457·4 | 3461·9 | 3466·3 | 3470·7 | 4·4 |
| 157 | 23475·1 | 3479·5 | 3483·9 | 3488·3 | 3492·7 | 3497·1 | 3501·5 | 3505·9 | 3510·3 | 3514·7 | 4·4 |
| 158 | 23519·1 | 3523·5 | 3527·9 | 3532·3 | 3536·7 | 3541·1 | 3545·4 | 3549·8 | 3554·2 | 3558·6 | 4·4 |
| 159 | 23563·0 | 3567·3 | 3571·7 | 3576·1 | 3580·4 | 3584·8 | 3589·1 | 3593·5 | 3597·9 | 3602·2 | 4·4 |
| 160 | 23606·0 | 3610·9 | 3615·3 | 3619·6 | 3624·0 | 3628·3 | 3632·6 | 3637·0 | 3641·3 | 3645·7 | 4·3 |
| 161 | 23650·0 | 3654·3 | 3658·7 | 3663·0 | 3667·3 | 3671·6 | 3676·0 | 3680·3 | 3684·6 | 3688·9 | 4·3 |
| 162 | 23693·3 | 3697·6 | 3701·9 | 3706·2 | 3710·5 | 3714·8 | 3719·1 | 3723·4 | 3727·7 | 3732·0 | 4·3 |
| 163 | 23736·3 | 3740·6 | 3744·9 | 3749·2 | 3753·5 | 3757·8 | 3762·1 | 3766·4 | 3770·6 | 3774·9 | 4·3 |
| 164 | 23779·2 | 3783·5 | 3787·8 | 3792·0 | 3796·3 | 3800·6 | 3804·9 | 3809·1 | 3813·4 | 3817·6 | 4·3 |
| 165 | 23821·9 | 3826·2 | 3830·4 | 3834·7 | 3838·9 | 3843·2 | 3847·4 | 3851·7 | 3855·9 | 3860·2 | 4·3 |
| 166 | 23864·4 | 3868·7 | 3872·9 | 3877·2 | 3881·4 | 3885·6 | 3889·9 | 3894·1 | 3898·3 | 3902·5 | 4·2 |
| 167 | 23906·8 | 3911·0 | 3915·2 | 3919·5 | 3923·7 | 3927·9 | 3932·1 | 3936·3 | 3940·5 | 3944·7 | 4·2 |
| 168 | 23949·0 | 3953·2 | 3957·4 | 3961·6 | 3965·8 | 3970·0 | 3974·2 | 3978·4 | 3982·6 | 3986·7 | 4·2 |
| 169 | 23990·9 | 3995·1 | 3999·3 | 4003·5 | 4007·7 | 4011·9 | 4016·0 | 4020·2 | 4024·4 | 4028·6 | 4·2 |
| 170 | 24032·7 | 4036·9 | 4041·1 | 4045·2 | 4049·4 | 4053·6 | 4057·7 | 4061·9 | 4066·0 | 4070·2 | 4·2 |
| 171 | 24074·3 | 4078·5 | 4082·6 | 4086·8 | 4090·9 | 4095·1 | 4099·2 | 4103·3 | 4107·5 | 4111·6 | 4·1 |
| 172 | 24115·7 | 4119·9 | 4124·0 | 4128·1 | 4132·3 | 4136·4 | 4140·5 | 4144·6 | 4148·7 | 4152·9 | 4·1 |
| 173 | 24157·0 | 4161·1 | 4165·2 | 4169·3 | 4173·4 | 4177·5 | 4181·6 | 4185·7 | 4189·8 | 4193·9 | 4·1 |
| 174 | 24198·0 | 4202·1 | 4206·2 | 4210·3 | 4214·4 | 4218·5 | 4222·6 | 4226·7 | 4230·8 | 4234·8 | 4·1 |
| 175 | 24238·9 | 4243·0 | 4247·1 | 4251·2 | 4255·3 | 4259·3 | 4263·4 | 4267·5 | 4271·5 | 4275·6 | 4·1 |
| 176 | 24279·6 | 4283·7 | 4287·8 | 4291·8 | 4295·9 | 4300·0 | 4304·0 | 4308·0 | 4312·1 | 4316·1 | 4·1 |
| 177 | 24320·2 | 4324·2 | 4328·3 | 4332·3 | 4336·4 | 4340·4 | 4344·4 | 4348·5 | 4352·5 | 4356·5 | 4·0 |
| 178 | 24360·5 | 4364·6 | 4368·6 | 4372·6 | 4376·6 | 4380·7 | 4384·7 | 4388·7 | 4392·7 | 4396·7 | 4·0 |
| 179 | 24400·7 | 4404·7 | 4408·8 | 4412·8 | 4416·8 | 4420·8 | 4424·8 | 4428·8 | 4432·8 | 4436·8 | 4·0 |
| 180 | 24440·8 | 4444·7 | 4448·7 | 4452·7 | 4456·7 | 4460·7 | 4464·7 | 4468·7 | 4472·6 | 4476·6 | 4·0 |
| 181 | 24480·6 | 4484·6 | 4488·5 | 4492·5 | 4496·5 | 4500·5 | 4504·4 | 4508·4 | 4512·4 | 4516·3 | 4·0 |
| 182 | 24520·3 | 4524·2 | 4528·2 | 4532·2 | 4536·1 | 4540·1 | 4544·0 | 4548·0 | 4551·9 | 4555·9 | 4·0 |
| 183 | 24559·8 | 4563·7 | 4567·7 | 4571·6 | 4575·6 | 4579·5 | 4583·4 | 4587·4 | 4591·3 | 4595·2 | 3·9 |
| 184 | 24599·2 | 4603·1 | 4607·0 | 4610·9 | 4614·9 | 4618·8 | 4622·7 | 4626·6 | 4630·5 | 4634·4 | 3·9 |
| 185 | 24638·4 | 4642·3 | 4646·2 | 4650·1 | 4654·0 | 4657·9 | 4661·8 | 4665·7 | 4669·6 | 4673·5 | 3·9 |
| 186 | 24677·4 | 4681·3 | 4685·2 | 4689·1 | 4693·0 | 4696·9 | 4700·8 | 4704·6 | 4708·5 | 4712·4 | 3·9 |
| 187 | 24716·3 | 4720·2 | 4724·1 | 4727·9 | 4731·8 | 4735·7 | 4739·6 | 4743·4 | 4747·3 | 4751·2 | 3·9 |
| 188 | 24755·0 | 4758·9 | 4762·8 | 4766·7 | 4770·5 | 4774·4 | 4778·2 | 4782·1 | 4786·0 | 4789·8 | 3·9 |
| 189 | 24793·7 | 4797·5 | 4801·4 | 4805·2 | 4809·1 | 4812·9 | 4816·8 | 4820·6 | 4824·5 | 4828·3 | 3·8 |
| 190 | 24832·2 | 4836·0 | 4839·8 | 4843·7 | 4847·5 | 4851·4 | 4855·2 | 4859·0 | 4862·8 | 4866·7 | 3·8 |
| 191 | 24870·5 | 4874·3 | 4878·1 | 4882·0 | 4885·8 | 4889·6 | 4893·4 | 4897·3 | 4901·1 | 4904·9 | 3·8 |
| 192 | 24908·7 | 4912·5 | 4916·3 | 4920·1 | 4923·9 | 4927·7 | 4931·5 | 4935·3 | 4939·1 | 4942·9 | 3·8 |
| 193 | 24946·7 | 4950·5 | 4954·3 | 4958·1 | 4961·9 | 4965·7 | 4969·4 | 4973·2 | 4977·0 | 4980·7 | 3·8 |
| 194 | 24984·5 | 4988·3 | 4992·1 | 4995·8 | 4999·6 | 5003·4 | 5007·1 | 5010·9 | 5014·7 | 5018·4 | 3·8 |
| 195 | 25022·2 | 5025·9 | 5029·7 | 5033·4 | 5037·2 | 5040·9 | 5044·7 | 5048·4 | 5052·1 | 5055·9 | 3·7 |
| 196 | 25059·6 | 5063·4 | 5067·1 | 5070·8 | 5074·6 | 5078·3 | 5082·0 | 5085·7 | 5089·4 | 5093·1 | 3·7 |
| 197 | 25096·9 | 5100·6 | 5104·3 | 5108·0 | 5111·7 | 5115·4 | 5119·1 | 5122·8 | 5126·5 | 5130·2 | 3·7 |
| 198 | 25133·9 | 5137·5 | 5141·2 | 5144·9 | 5148·6 | 5152·3 | 5156·0 | 5159·6 | 5163·3 | 5166·9 | 3·7 |

## Table III. $\frac{d^2}{w}s = S_V - S_v$—(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | |
| 199 | 25170·6 | 5174·3 | 5177·9 | 5181·6 | 5185·2 | 5188·9 | 5192·5 | 5196·2 | 5199·8 | 5203·4 | 3·6 |
| 200 | 25207·1 | 5210·7 | 5214·3 | 5218·0 | 5221·6 | 5225·2 | 5228·8 | 5232·5 | 5236·1 | 5239·7 | 3·6 |
| 201 | 25243·3 | 5246·9 | 5250·5 | 5254·1 | 5257·7 | 5261·3 | 5264·9 | 5268·5 | 5272·1 | 5275·7 | 3·6 |
| 202 | 25279·2 | 5282·8 | 5286·4 | 5290·0 | 5293·6 | 5297·2 | 5300·7 | 5304·2 | 5307·8 | 5311·4 | 3·6 |
| 203 | 25314·9 | 5318·5 | 5322·0 | 5325·6 | 5329·1 | 5332·7 | 5336·2 | 5339·7 | 5343·3 | 5346·8 | 3·5 |
| 204 | 25350·3 | 5353·8 | 5357·3 | 5360·9 | 5364·4 | 5367·9 | 5371·4 | 5374·9 | 5378·4 | 5381·9 | 3·5 |
| 205 | 25385·4 | 5388·9 | 5392·4 | 5395·9 | 5399·4 | 5402·9 | 5406·3 | 5409·8 | 5413·3 | 5416·7 | 3·5 |
| 206 | 25420·2 | 5423·7 | 5427·1 | 5430·6 | 5434·1 | 5437·5 | 5441·0 | 5444·4 | 5447·8 | 5451·3 | 3·5 |
| 207 | 25454·7 | 5458·1 | 5461·6 | 5465·0 | 5468·4 | 5471·9 | 5475·3 | 5478·7 | 5482·1 | 5485·5 | 3·4 |
| 208 | 25488·9 | 5492·3 | 5495·7 | 5499·1 | 5502·5 | 5505·9 | 5509·3 | 5512·7 | 5516·1 | 5519·4 | 3·4 |
| 209 | 25522·8 | 5526·2 | 5529·6 | 5532·9 | 5536·3 | 5539·7 | 5543·0 | 5546·4 | 5549·7 | 5553·1 | 3·4 |
| 210 | 25556·4 | 5559·8 | 5563·1 | 5566·4 | 5569·8 | 5573·1 | 5576·5 | 5579·8 | 5583·1 | 5586·4 | 3·3 |
| 211 | 25589·7 | 5593·0 | 5596·4 | 5599·7 | 5603·0 | 5606·3 | 5609·6 | 5612·9 | 5616·2 | 5619·5 | 3·3 |
| 212 | 25622·8 | 5626·1 | 5629·3 | 5632·6 | 5635·9 | 5639·2 | 5642·5 | 5645·7 | 5649·0 | 5652·3 | 3·3 |
| 213 | 25655·5 | 5658·8 | 5662·0 | 5665·3 | 5668·6 | 5671·8 | 5675·1 | 5678·3 | 5681·5 | 5684·8 | 3·2 |
| 214 | 25688·0 | 5691·2 | 5694·5 | 5697·7 | 5700·9 | 5704·2 | 5707·4 | 5710·6 | 5713·8 | 5717·0 | 3·2 |
| 215 | 25720·2 | 5723·4 | 5726·6 | 5729·9 | 5733·1 | 5736·3 | 5739·5 | 5742·6 | 5745·8 | 5749·0 | 3·2 |
| 216 | 25752·2 | 5755·4 | 5758·6 | 5761·8 | 5764·9 | 5768·1 | 5771·3 | 5774·4 | 5777·6 | 5780·8 | 3·2 |
| 217 | 25783·9 | 5787·1 | 5790·2 | 5793·4 | 5796·6 | 5799·7 | 5802·9 | 5806·0 | 5809·1 | 5812·2 | 3·1 |
| 218 | 25815·4 | 5818·5 | 5821·6 | 5824·8 | 5827·9 | 5831·0 | 5834·1 | 5837·3 | 5840·4 | 5843·5 | 3·1 |
| 219 | 25846·6 | 5849·7 | 5852·8 | 5855·9 | 5859·0 | 5862·1 | 5865·2 | 5868·3 | 5871·4 | 5874·4 | 3·1 |
| 220 | 25877·5 | 5880·6 | 5883·7 | 5886·8 | 5889·9 | 5893·0 | 5896·0 | 5899·1 | 5902·1 | 5905·2 | 3·1 |
| 221 | 25908·3 | 5911·3 | 5914·4 | 5917·4 | 5920·5 | 5923·6 | 5926·6 | 5929·6 | 5932·7 | 5935·7 | 3·0 |
| 222 | 25938·7 | 5941·8 | 5944·8 | 5947·8 | 5950·9 | 5953·9 | 5956·9 | 5959·9 | 5963·0 | 5966·0 | 3·0 |
| 223 | 25969·0 | 5972·0 | 5975·0 | 5978·0 | 5981·0 | 5984·0 | 5987·0 | 5990·0 | 5993·0 | 5996·0 | 3·0 |
| 224 | 25999·0 | 6002·0 | 6004·9 | 6007·9 | 6010·9 | 6013·9 | 6016·9 | 6019·8 | 6022·8 | 6025·8 | 3·0 |
| 225 | 26028·7 | 6031·7 | 6034·7 | 6037·6 | 6040·6 | 6043·6 | 6046·5 | 6049·5 | 6052·4 | 6055·3 | 3·0 |
| 226 | 26058·3 | 6061·2 | 6064·2 | 6067·1 | 6070·0 | 6073·0 | 6075·9 | 6078·8 | 6081·7 | 6084·6 | 2·9 |
| 227 | 26087·5 | 6090·5 | 6093·4 | 6096·3 | 6099·2 | 6102·1 | 6105·0 | 6107·9 | 6110·8 | 6113·7 | 2·9 |
| 228 | 26116·6 | 6119·4 | 6122·3 | 6125·2 | 6128·1 | 6131·0 | 6133·9 | 6136·7 | 6139·6 | 6142·5 | 2·9 |
| 229 | 26145·3 | 6148·2 | 6151·0 | 6153·9 | 6156·8 | 6159·6 | 6162·5 | 6165·3 | 6168·1 | 6171·0 | 2·9 |
| 230 | 26173·8 | 6176·7 | 6179·5 | 6182·3 | 6185·2 | 6188·0 | 6190·8 | 6193·6 | 6196·5 | 6199·3 | 2·8 |
| 231 | 26202·1 | 6204·9 | 6207·7 | 6210·5 | 6213·3 | 6216·2 | 6218·9 | 6221·7 | 6224·5 | 6227·3 | 2·8 |
| 232 | 26230·1 | 6232·9 | 6235·7 | 6238·5 | 6241·3 | 6244·1 | 6246·8 | 6249·6 | 6252·3 | 6255·1 | 2·8 |
| 233 | 26257·9 | 6260·6 | 6263·4 | 6266·2 | 6268·9 | 6271·7 | 6274·5 | 6277·2 | 6279·9 | 6282·7 | 2·8 |
| 234 | 26285·4 | 6288·2 | 6290·9 | 6293·7 | 6296·4 | 6299·1 | 6301·9 | 6304·6 | 6307·3 | 6310·0 | 2·7 |
| 235 | 26312·7 | 6315·5 | 6318·2 | 6320·9 | 6323·6 | 6326·3 | 6329·0 | 6331·7 | 6334·4 | 6337·1 | 2·7 |
| 236 | 26339·8 | 6342·5 | 6345·2 | 6347·9 | 6350·6 | 6353·3 | 6356·0 | 6358·6 | 6361·3 | 6364·0 | 2·7 |
| 237 | 26366·7 | 6369·3 | 6372·0 | 6374·7 | 6377·3 | 6380·0 | 6382·7 | 6385·3 | 6388·0 | 6390·6 | 2·7 |
| 238 | 26393·3 | 6395·9 | 6398·6 | 6401·2 | 6403·9 | 6406·5 | 6409·2 | 6411·8 | 6414·4 | 6417·1 | 2·6 |
| 239 | 26419·7 | 6422·3 | 6424·9 | 6427·6 | 6430·2 | 6432·8 | 6435·4 | 6438·0 | 6440·7 | 6443·3 | 2·6 |
| 240 | 26445·9 | 6448·5 | 6451·1 | 6453·7 | 6456·3 | 6458·9 | 6461·6 | 6464·1 | 6466·7 | 6469·2 | 2·6 |
| 241 | 26471·8 | 6474·4 | 6477·0 | 6479·6 | 6482·2 | 6484·8 | 6487·3 | 6489·9 | 6492·4 | 6495·0 | 2·6 |
| 242 | 26497·6 | 6500·1 | 6502·7 | 6505·3 | 6507·8 | 6510·4 | 6512·9 | 6515·5 | 6518·0 | 6520·6 | 2·6 |
| 243 | 26523·1 | 6525·6 | 6528·2 | 6530·7 | 6533·3 | 6535·8 | 6538·3 | 6540·9 | 6543·4 | 6545·9 | 2·5 |
| 244 | 26548·4 | 6550·9 | 6553·5 | 6556·0 | 6558·5 | 6561·0 | 6563·5 | 6566·0 | 6568·5 | 6571·0 | 2·5 |
| 245 | 26573·5 | 6576·0 | 6578·5 | 6581·0 | 6583·5 | 6586·1 | 6588·5 | 6591·0 | 6593·5 | 6596·0 | 2·5 |
| 246 | 26598·5 | 6600·9 | 6603·4 | 6605·9 | 6608·4 | 6610·9 | 6613·3 | 6615·8 | 6618·2 | 6620·7 | 2·5 |
| 247 | 26623·2 | 6625·6 | 6628·1 | 6630·5 | 6633·0 | 6635·5 | 6637·9 | 6640·4 | 9642·8 | 6645·2 | 2·5 |
| 248 | 26647·7 | 6650·1 | 6652·6 | 6655·0 | 6657·4 | 6659·9 | 6662·3 | 6664·7 | 6667·1 | 6669·6 | 2·4 |
| 240 | 26672·0 | 6674·4 | 6676·8 | 6679·3 | 6681·7 | 6684·1 | 6686·5 | 6688·9 | 6691·3 | 6693·7 | 2·4 |

## TABLE IV.

### Time and Velocity Table. $\frac{d^2}{w} t = T_V - T_v$.*

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | |
| 40 | 5·0000 | 5·1052 | 5·2099 | 5·3140 | 5·4175 | 5·5206 | 5·6230 | 5·7250 | 5·8264 | 5·9273 | ·1027 |
| 41 | 6·0276 | 6·1275 | 6·2268 | 6·3256 | 6·4238 | 6·5216 | 6·6188 | 6·7155 | 6·8117 | 6·9075 | ·0975 |
| 42 | 7·0027 | 7·0974 | 7·1916 | 7·2854 | 7·3786 | 7·4714 | 7·5637 | 7·6556 | 7·7470 | 7·8397 | ·0925 |
| 43 | 7·9283 | 8·0183 | 8·1078 | 8·1969 | 8·2855 | 8·3737 | 8·4614 | 8·5487 | 8·6355 | 8·7219 | ·0879 |
| 44 | 8·8079 | 8·8935 | 8·9786 | 9·0633 | 9·1476 | 9·2315 | 9·3150 | 9·3981 | 9·4808 | 9·5631 | ·0837 |
| 45 | 9·6451 | 9·7266 | 9·8077 | 9·8885 | 9·9689 | 0·0488 | 0·1285 | 0·2077 | 0·2866 | 0·3651 | ·0798 |
| 46 | 10·4433 | 0·5211 | 0·5986 | 0·6757 | 0·7525 | 0·8289 | 0·9049 | 0·9807 | 1·0560 | 1·1311 | ·0762 |
| 47 | 11·2058 | 1·2803 | 1·3544 | 1·4281 | 1·5016 | 1·5747 | 1·6475 | 1·7200 | 1·7922 | 1·8641 | ·0730 |
| 48 | 11·9357 | 2·0069 | 2·0779 | 2·1486 | 2·2189 | 2·2890 | 2·3588 | 2·4283 | 2·4975 | 2·5664 | ·0699 |
| 49 | 12·6350 | 2·7033 | 2·7713 | 2·8391 | 2·9066 | 2·9738 | 2·0408 | 3·1075 | 3·1739 | 3 2401 | ·0670 |
| 50 | 13·3060 | 3·3716 | 3·4369 | 3·5020 | 3·5669 | 3·6315 | 3·6958 | 3·7598 | 3·8236 | 3·8872 | ·0644 |
| 51 | 13·9505 | 4 0135 | 4·0763 | 4·1389 | 4·2012 | 4·2632 | 4·3250 | 4·3866 | 4·4479 | 4·5090 | ·0619 |
| 52 | 14·5699 | 4·6305 | 4·6909 | 4·7511 | 4·8110 | 4·8708 | 4·9303 | 4·9896 | 5·0486 | 5·1075 | ·0596 |
| 53 | 15·1661 | 5·2245 | 5·2827 | 5·3407 | 5·3985 | 5·4560 | 5·5133 | 5·5705 | 5·6274 | 5·6841 | ·0574 |
| 54 | 15·7406 | 5·7969 | 5·8530 | 5·9089 | 5·9646 | 6·0201 | 6·0754 | 6·1304 | 6·1853 | 6·2400 | ·0553 |
| 55 | 16·2945 | 6·3488 | 6·4029 | 6·4568 | 6·5105 | 6·5641 | 6·6174 | 6·6705 | 6·7235 | 6·7762 | ·0534 |
| 56 | 16·8288 | 6·8812 | 6·9334 | 6·9854 | 7·0373 | 7·0890 | 7·1405 | 7·1918 | 7·2430 | 7·2940 | ·0516 |
| 57 | 17·3448 | 7·3955 | 7·4460 | 7·4963 | 7·5464 | 7·5964 | 7·6462 | 7·6959 | 7·7454 | 7·7947 | ·0499 |
| 58 | 17·8438 | 7·8928 | 7 9417 | 7·9904 | 8·0389 | 8·0873 | 8·1356 | 8·1837 | 8·2316 | 8·2794 | ·0483 |
| 59 | 18·3271 | 8·3746 | 8·4220 | 8·4692 | 8·5163 | 8·5632 | 8·6100 | 8·6566 | 8·7031 | 8·7494 | ·0468 |
| 60 | 18·7957 | 8·8417 | 8·8877 | 8·9334 | 8·9791 | 9·0246 | 9·0700 | 9·1152 | 9·1603 | 9·2052 | ·0454 |
| 61 | 19·2501 | 9·2947 | 9·3393 | 9·3837 | 9·4280 | 9·4721 | 9·5161 | 9·5600 | 9·6037 | 9·6473 | ·0441 |
| 62 | 19·6908 | 9·7341 | 9·7773 | 9·8204 | 9·8633 | 9·9062 | 9·9489 | 9·9914 | 0·0338 | 0·0761 | ·0428 |
| 63 | 20·1183 | 0·1604 | 0·2023 | 0·2441 | 0·2858 | 0·3273 | 0·3687 | 0·4100 | 0·4512 | 0·4922 | ·0415 |
| 64 | 20·5332 | 0·5740 | 0·1647 | 0·6552 | 0·6957 | 0·7360 | 0·7762 | 0·8163 | 0·8563 | 0·8962 | ·0403 |
| 65 | 20·9359 | 0·9755 | 1·0151 | 1·0544 | 1·0937 | 1·1328 | 1·1718 | 1·2107 | 1·2495 | 1·2881 | ·0391 |
| 66 | 21·3267 | 1·3651 | 1·4034 | 1·4416 | 1·4797 | 1·5177 | 1·5555 | 1·5933 | 1·6309 | 1·6684 | ·0379 |
| 67 | 21·7059 | 1·7432 | 1·7804 | 1·8175 | 1·8545 | 1·8914 | 1·9281 | 1·9648 | 2·0014 | 2·0378 | ·0368 |
| 68 | 22·0742 | 2·1105 | 2·1466 | 2·1827 | 2·2186 | 2·2545 | 2·2902 | 2·3259 | 2·3614 | 2·3969 | ·0358 |
| 69 | 22·4322 | 2·4675 | 2·5027 | 2·5377 | 2·5727 | 2·6076 | 2·6424 | 2·6771 | 2·7117 | 2·7462 | ·0348 |
| 70 | 22·7806 | 2·8150 | 2·8492 | 2·8833 | 2·9174 | 2·9513 | 2·9852 | 3·0189 | 3·0526 | 3·0862 | ·0339 |
| 71 | 23·1196 | 3·1530 | 3·1863 | 3·2195 | 3·2526 | 3·2856 | 3·3185 | 3·3513 | 3·3840 | 3·4167 | ·0330 |
| 72 | 23·4492 | 3·4816 | 3·5140 | 3·5462 | 3·5784 | 3·6105 | 3·6424 | 3·6743 | 3·7061 | 3·7378 | ·0320 |
| 73 | 23·7694 | 3·8009 | 3·8323 | 3·8636 | 3·8949 | 3·9260 | 3·9571 | 3 9881 | 4·0189 | 4·0497 | ·0311 |
| 74 | 24·0804 | 4·1110 | 4·1416 | 4·1720 | 4·2024 | 4·2326 | 4·2628 | 4·2929 | 4·3230 | 4·3529 | ·0302 |
| 75 | 24·3828 | 4·4125 | 4·4422 | 4·4719 | 4·5014 | 4·5308 | 4·5602 | 4·5895 | 4·6187 | 4·6478 | ·0294 |
| 76 | 24·6769 | 4·7058 | 4·7347 | 4·7635 | 4·7922 | 4·8208 | 4·8493 | 4·8777 | 4·9060 | 4·9343 | ·0286 |
| 77 | 24·9624 | 4·9905 | 5·0185 | 5·0464 | 5·0742 | 5·1020 | 5·1296 | 5·1572 | 5·1847 | 5·2121 | ·0277 |
| 78 | 25·2394 | 5·2666 | 5·2937 | 5·3208 | 5.3478 | 5·3747 | 5·4015 | 5·4282 | 5·4549 | 5·4814 | ·0268 |
| 79 | 25·5079 | 5·5343 | 5·2606 | 5·5869 | 5·6130 | 5·6391 | 5 6652 | 5·6911 | 5·7170 | 5·7428 | ·0261 |
| 80 | 25·7685 | 5·7941 | 5·8197 | 5·8452 | 5·8706 | 5·8959 | 5·9212 | 5·9463 | 5·9714 | 5·9965 | ·0253 |
| 81 | 26·0214 | 6·0463 | 6·0711 | 6·0959 | 6·1205 | 6·1451 | 6·1696 | 6·1941 | 6·2184 | 6·2427 | ·0245 |
| 82 | 26·2669 | 6·2910 | 6·3151 | 6·3390 | 6·3629 | 6·3867 | 6·4104 | 6·4340 | 6·4576 | 6·4810 | ·0237 |
| 83 | 26·5044 | 6·5277 | 6 5509 | 6·5740 | 6·5971 | 6·6201 | 6·6430 | 6·6658 | 6·6885 | 6·7111 | ·0229 |
| 84 | 26·7337 | 6·7562 | 6·7786 | 6·8009 | 6·8232 | 6·8454 | 6·8675 | 6·8895 | 6·9114 | 6·9333 | ·0221 |
| 85 | 26·9551 | 6·9768 | 6·9984 | 7·0200 | 7·0415 | 7·0629 | 7·0842 | 7·1055 | 7·1267 | 7·1478 | ·0214 |
| 86 | 27·1688 | 7·1898 | 7·2107 | 7·2315 | 7·2522 | 7·2729 | 7·2935 | 7·3140 | 7·3345 | 7·3549 | ·0206 |
| 87 | 27·3752 | 7·3954 | 7·4156 | 7·4357 | 7·4558 | 7·4757 | 7·4956 | 7·5155 | 7·5353 | 7·5550 | ·0199 |
| 88 | 27·5746 | 7·5942 | 7·6137 | 7·6332 | 7·6526 | 7·6719 | 7·6912 | 7·7104 | 7·7295 | 7·7486 | ·0193 |
| 89 | 27·7677 | 7·7866 | 7·8055 | 7·8244 | 7·8431 | 7·8618 | 7·8805 | 7·8991 | 7·9176 | 7·9360 | ·0187 |
| 90 | 27·9544 | 7.9727 | 7·9909 | 8·0091 | 8·0272 | 8·0452 | 8·0632 | 8·0812 | 8·0990 | 8·1168 | ·0180 |

* Report on Experiments made with the Bashforth Chronograph. Part II. 1878-9.

TABLE IV. $\frac{d^2}{w}t = T_V - T_v$—(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | |
| 91 | 28·1346 | 8·1523 | 8·1699 | 8·1875 | 8·2050 | 8·2225 | 8·2399 | 8·2573 | 8·2746 | 8·2918 | ·0174 |
| 92 | 28·3090 | 8·3261 | 8·3432 | 8·3602 | 8·3772 | 8·3941 | 8·4109 | 8·4277 | 8·4445 | 8·4611 | ·0169 |
| 93 | 28·4778 | 8·4943 | 8·5109 | 8·5273 | 8·5437 | 8·5601 | 8·5764 | 8·5927 | 8·6089 | 8·6250 | ·0163 |
| 94 | 28·6411 | 8·6572 | 8·6732 | 8·6892 | 8·7051 | 8·7209 | 8·7367 | 8·7525 | 8·7682 | 8·7838 | ·0158 |
| 65 | 28·7994 | 8·8150 | 8·8305 | 8·8459 | 8·8613 | 8·8767 | 8·8920 | 8·9073 | 8·9225 | 8·9376 | ·0153 |
| 96 | 28·9528 | 8·9678 | 8·9828 | 8·9978 | 9·0128 | 9·0276 | 9·0425 | 9·0573 | 9·0720 | 9·0867 | ·0149 |
| 97 | 29·1014 | 9·1160 | 9·1306 | 9·1451 | 9·1595 | 9·1740 | 9·1884 | 9·2027 | 9·2170 | 9·2312 | ·0144 |
| 98 | 29·2454 | 9·2596 | 9·2737 | 9·2878 | 9·3018 | 9·3158 | 9·3298 | 9·3437 | 9·3575 | 9·3713 | ·0140 |
| 99 | 29·3851 | 9·3989 | 9·4126 | 9·4262 | 9·4398 | 9·4534 | 9·4670 | 9·4805 | 9·4939 | 9·5073 | ·0136 |
| 100 | 29·5207 | ·5340 | ·5473 | ·5606 | ·5738 | ·5869 | ·6001 | ·6132 | ·6262 | ·6392 | ·0132 |
| 101 | 29·6522 | ·6651 | ·6780 | ·6908 | ·7036 | ·7164 | ·7291 | ·7418 | ·7544 | ·7670 | ·0127 |
| 102 | 29·7796 | ·7921 | ·8046 | ·8170 | ·8294 | ·8417 | ·8540 | ·8662 | ·8783 | ·8904 | ·0123 |
| 103 | 29·9024 | ·9144 | ·9262 | ·9380 | ·9496 | ·9612 | ·9727 | ·9841 | ·9954 | ·0066 | ·0115 |
| 104 | 30·0177 | ·0287 | ·0396 | ·0504 | ·0610 | ·0716 | ·0820 | ·0923 | ·1025 | ·1126 | ·0105 |
| 105 | 30·1226 | ·1325 | ·1423 | ·1520 | ·1615 | ·1710 | ·1804 | ·1897 | ·1988 | ·2079 | ·0094 |
| 106 | 30·2170 | ·2259 | ·2347 | ·2435 | ·2522 | ·2609 | ·2694 | ·2680 | ·2864 | ·2948 | ·0086 |
| 107 | 30·3031 | ·3114 | ·3196 | ·3278 | ·3359 | ·3439 | ·3520 | ·3599 | ·3678 | ·3757 | ·0080 |
| 108 | 30·3835 | ·3913 | ·3990 | ·4067 | ·4143 | ·4219 | ·4295 | ·4370 | ·4445 | ·4519 | ·0076 |
| 109 | 30·4593 | ·4667 | ·4740 | ·4813 | ·4885 | ·4958 | ·5030 | ·5101 | ·5172 | ·5243 | ·0072 |
| 110 | 30·5314 | ·5384 | ·5454 | ·5524 | ·5593 | ·5662 | ·5731 | ·5800 | ·5868 | ·5936 | ·0069 |
| 111 | 30·6004 | ·6071 | ·6139 | ·6206 | ·6272 | ·6339 | ·6405 | ·6471 | ·6537 | ·6603 | ·0066 |
| 112 | 30·6668 | ·6733 | ·6798 | ·6863 | ·6928 | ·6992 | ·7056 | ·7120 | ·7184 | ·7248 | ·0064 |
| 113 | 30·7311 | ·7374 | ·7437 | ·7500 | ·7563 | ·7625 | ·7688 | ·7750 | ·7812 | ·7874 | ·0062 |
| 114 | 30·7936 | ·7997 | ·8059 | ·8120 | ·8181 | ·8242 | ·8303 | ·8364 | ·8424 | ·8484 | ·0061 |
| 115 | 30·8545 | ·8605 | ·8665 | ·8726 | ·8787 | ·8847 | ·8906 | ·8965 | ·9024 | ·9083 | ·0059 |
| 116 | 30·9142 | ·9200 | ·9259 | ·9317 | ·9375 | ·9433 | ·9490 | ·9548 | ·9605 | ·9663 | ·0058 |
| 117 | 30·9720 | ·9777 | ·9833 | ·9890 | ·9947 | ·0003 | ·0059 | ·0115 | ·0171 | ·0227 | ·0056 |
| 118 | 31·0283 | ·0338 | ·0394 | ·0449 | ·0504 | ·0559 | ·0614 | ·0669 | ·0723 | ·0778 | ·0055 |
| 119 | 31·0832 | ·0886 | ·0940 | ·0994 | ·1048 | ·1101 | ·1154 | ·1208 | ·1261 | ·1314 | ·0054 |
| 120 | 31·1367 | ·1420 | ·1473 | ·1525 | ·1578 | ·1630 | ·1682 | ·1734 | ·1786 | ·1838 | ·0052 |
| 121 | 31·1889 | ·1941 | ·1992 | ·2043 | ·2095 | ·2146 | ·2196 | ·2247 | ·2298 | ·2348 | ·0051 |
| 122 | 31·2399 | ·2449 | ·2499 | ·2549 | ·2599 | ·2649 | ·2698 | ·2748 | ·2797 | ·2847 | ·0050 |
| 123 | 31·2896 | ·2945 | ·2994 | ·3043 | ·3091 | ·3140 | ·3188 | ·3237 | ·3285 | ·3333 | ·0049 |
| 124 | 31·3381 | ·3429 | ·3477 | ·3524 | ·3572 | ·3619 | ·3667 | ·3714 | ·3761 | ·3808 | ·0047 |
| 125 | 31·3855 | ·3902 | ·3948 | ·3995 | ·4041 | ·4088 | ·4134 | ·4180 | ·4226 | ·4272 | ·0046 |
| 126 | 31·4318 | ·4364 | ·4410 | ·4455 | ·4501 | ·4546 | ·4591 | ·4636 | ·4681 | ·4726 | ·0045 |
| 127 | 31·4771 | ·4816 | ·4860 | ·4905 | ·4949 | ·4993 | ·5038 | ·5082 | ·5126 | ·5170 | ·0044 |
| 128 | 31·5214 | ·5257 | ·5301 | ·5345 | ·5388 | ·5431 | ·5475 | ·5518 | ·5561 | ·5604 | ·0043 |
| 129 | 31·5647 | ·5690 | ·5732 | ·5775 | ·5818 | ·5860 | ·5902 | ·5945 | ·5987 | ·6029 | ·0042 |
| 130 | 31·6071 | ·6113 | ·6155 | ·6196 | ·6238 | ·6280 | ·6321 | ·6362 | ·6404 | ·6445 | ·0042 |
| 131 | 31·6486 | ·6527 | ·6568 | ·6609 | ·6650 | ·6690 | ·6731 | ·6772 | ·6812 | ·6852 | ·0041 |
| 132 | 31·6893 | ·6933 | ·6973 | ·7013 | ·7053 | ·7093 | ·7133 | ·7173 | ·7212 | ·7252 | ·0040 |
| 133 | 31·7291 | ·7331 | ·7370 | ·7410 | ·7449 | ·7488 | ·7527 | ·7566 | ·7605 | ·7644 | ·0039 |
| 134 | 31·7682 | ·7721 | ·7760 | ·7798 | ·7837 | ·7875 | ·7913 | ·7952 | ·7990 | ·8028 | ·0038 |
| 135 | 31·8066 | ·8104 | ·8142 | ·8179 | ·8217 | ·8255 | ·8292 | ·8330 | ·8367 | ·8405 | ·0038 |
| 136 | 31·8442 | ·8479 | ·8517 | ·8554 | ·8591 | ·8628 | ·8665 | ·8702 | ·8738 | ·8775 | ·0037 |
| 137 | 31·8812 | ·8848 | ·8885 | ·8921 | ·8958 | ·8994 | ·9030 | ·9067 | ·9103 | ·9139 | ·0036 |
| 138 | 31·9175 | ·9211 | ·9247 | ·9282 | ·9318 | ·9354 | ·9390 | ·9425 | ·9461 | ·9496 | ·0036 |
| 139 | 31·9532 | ·9567 | ·9602 | ·9638 | ·9673 | 9708 | ·9743 | ·9778 | ·9813 | ·9848 | ·0035 |
| 140 | 31·9883 | ·9918 | ·9952 | ·9987 | ·0022 | ·0056 | ·0091 | ·0125 | ·0160 | ·0194 | ·0035 |
| 141 | 32·0228 | ·0263 | ·0297 | ·0331 | ·0365 | ·0399 | ·0433 | ·0467 | ·0501 | .0535 | ·0034 |
| 142 | 32·0569 | ·0602 | ·0636 | ·0670 | ·0703 | ·0737 | ·0770 | ·0804 | ·0837 | ·0870 | ·0034 |
| 143 | 32·0904 | ·0937 | ·0970 | ·1003 | ·1036 | ·1069 | ·1102 | ·1135 | ·1168 | ·1201 | ·0033 |
| 144 | 32·1234 | ·1267 | ·1299 | ·1332 | ·1364 | ·1397 | ·1430 | ·1462 | ·1494 | ·1527 | ·0033 |

**TABLE IV.** $\frac{d^2}{w}t = T_V - T_v$—(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. |
| 145 | 32·1559 | ·1591 | ·1624 | ·1656 | ·1688 | ·1720 | ·1752 | ·1784 | ·1816 | ·1848 | ·0032 |
| 146 | 32·1880 | ·1912 | ·1944 | ·1975 | ·2007 | ·2039 | ·2071 | ·2102 | ·2134 | ·2165 | ·0032 |
| 147 | 32·2197 | ·2228 | ·2260 | ·2291 | ·2322 | ·2354 | ·2385 | ·2416 | ·2447 | ·2478 | ·0031 |
| 148 | 32·2509 | ·2540 | ·2571 | ·2602 | ·2633 | ·2664 | ·2695 | ·2726 | ·2757 | ·2787 | ·0031 |
| 149 | 32·2818 | ·2849 | ·2879 | ·2910 | ·2940 | ·2971 | ·3001 | ·3032 | ·3062 | ·3093 | ·0030 |
| 150 | 32·3123 | ·3153 | ·3183 | ·3214 | ·3244 | ·3274 | ·3304 | ·3334 | ·3364 | ·3394 | ·0030 |
| 151 | 32·3424 | ·3454 | ·3484 | ·3514 | ·3543 | ·3573 | ·3603 | ·3633 | ·3662 | ·3692 | ·0030 |
| 152 | 32·3722 | ·3751 | ·3781 | ·3810 | ·3840 | ·3869 | ·3899 | ·3928 | ·3958 | ·3987 | ·0029 |
| 153 | 32·4016 | ·4046 | ·4075 | ·4104 | ·4133 | ·4162 | ·4192 | ·4221 | ·4250 | ·4279 | ·0029 |
| 154 | 32·4308 | ·4337 | ·4366 | ·4395 | ·4424 | ·4453 | ·4481 | ·4510 | ·4539 | ·4568 | ·0029 |
| 155 | 32·4597 | ·4625 | ·4654 | ·4683 | ·4711 | ·4740 | ·4768 | ·4797 | ·4825 | ·4854 | ·0029 |
| 156 | 32·4882 | ·4911 | ·4939 | ·4967 | ·4996 | ·5024 | ·5052 | ·5080 | ·5108 | ·5137 | ·0028 |
| 157 | 32·5165 | ·5193 | ·5221 | ·5249 | ·5277 | ·5305 | ·5333 | ·5361 | ·5389 | ·5416 | ·0028 |
| 158 | 32·5444 | ·5472 | ·5500 | ·5528 | ·5555 | ·5583 | ·5611 | ·5638 | ·5666 | ·5693 | ·0028 |
| 159 | 32·5721 | ·5748 | ·5776 | ·5803 | ·5831 | ·5858 | ·5885 | ·5913 | ·5940 | ·5967 | ·0027 |
| 160 | 32·5994 | ·6022 | ·6049 | ·6076 | ·6103 | ·6130 | ·6157 | ·6184 | ·6211 | ·6238 | ·0027 |
| 161 | 32·6265 | ·6292 | ·6319 | ·6346 | ·6373 | ·6400 | ·6426 | ·6453 | ·6480 | ·6506 | ·0027 |
| 162 | 32·6533 | ·6560 | ·6586 | ·6613 | ·6640 | ·6666 | ·6693 | ·6719 | ·6745 | ·6772 | ·0026 |
| 163 | 32·6798 | ·6825 | ·6851 | ·6877 | ·6903 | ·6930 | ·6956 | ·6982 | ·7008 | ·7034 | ·0026 |
| 164 | 32·7061 | ·7087 | ·7113 | ·7139 | ·7165 | ·7191 | ·7217 | ·7243 | ·7268 | ·7294 | ·0026 |
| 165 | 32·7320 | ·7346 | ·7372 | ·7398 | ·7423 | ·7449 | ·7475 | ·7500 | ·7526 | ·7552 | ·0026 |
| 166 | 32·7577 | ·7603 | ·7628 | ·7654 | ·7679 | ·7705 | ·7730 | ·7756 | ·7781 | ·7806 | ·0025 |
| 167 | 32·7832 | ·7857 | ·7882 | ·7908 | ·7933 | ·7958 | ·7983 | ·8008 | ·8034 | ·8059 | ·0025 |
| 168 | 32·8084 | ·8109 | ·8134 | ·8159 | ·8184 | ·8209 | ·8234 | ·8258 | ·8283 | ·8308 | ·0025 |
| 169 | 32·8333 | ·8358 | ·8383 | ·8407 | ·8432 | ·8457 | ·8481 | ·8506 | ·8531 | ·8555 | ·0025 |
| 170 | 32·8580 | ·8604 | ·8629 | ·8653 | ·8678 | ·8702 | ·8726 | ·8751 | ·8775 | ·8799 | ·0024 |
| 171 | 32·8824 | ·8848 | ·8872 | ·8896 | ·8921 | ·8945 | ·8969 | ·8993 | ·9017 | ·9041 | ·0024 |
| 172 | 32·9065 | ·9089 | ·9113 | ·9137 | ·9161 | ·9185 | ·9209 | ·9233 | ·9257 | ·9281 | ·0024 |
| 173 | 32·9304 | ·9328 | ·9352 | ·9376 | ·9399 | ·9423 | ·9447 | ·9470 | ·9494 | ·9518 | ·0024 |
| 174 | 32·9541 | ·9565 | ·9588 | ·9612 | ·9635 | ·9659 | ·9682 | ·9705 | ·9729 | ·9752 | ·0023 |
| 175 | 32·9776 | ·9799 | ·9822 | ·9845 | ·9869 | ·9892 | ·9915 | ·9938 | ·9961 | ·9985 | ·0023 |
| 176 | 33·0008 | ·0031 | ·0054 | ·0077 | ·0100 | ·0123 | ·0146 | ·0169 | ·0192 | ·0215 | ·0023 |
| 177 | 33·0237 | ·0260 | ·0283 | ·0306 | ·0329 | ·0351 | ·0374 | ·0397 | ·0420 | ·0412 | ·0023 |
| 178 | 33·0465 | ·0488 | ·0510 | ·0533 | ·0555 | ·0578 | ·0600 | ·0623 | ·0645 | ·0668 | ·0023 |
| 179 | 33·0690 | ·0713 | ·0735 | ·0757 | ·0780 | ·0802 | ·0824 | ·0847 | ·0869 | ·0891 | ·0022 |
| 180 | 33·0913 | ·0935 | ·0958 | ·0980 | ·1002 | ·1024 | ·1046 | ·1068 | ·1090 | ·1112 | ·0022 |
| 181 | 33·1134 | ·1156 | ·1178 | ·1200 | ·1222 | ·1244 | ·1266 | ·1287 | ·1309 | ·1331 | ·0022 |
| 182 | 33·1353 | ·1375 | ·1396 | ·1418 | ·1440 | ·1461 | ·1483 | ·1505 | ·1526 | ·1548 | ·0022 |
| 183 | 33·1569 | ·1591 | ·1613 | ·1634 | ·1656 | ·1677 | ·1698 | ·1720 | ·1741 | ·1763 | ·0021 |
| 184 | 33·1784 | ·1805 | ·1827 | ·1848 | ·1869 | ·1891 | ·1912 | ·1933 | ·1954 | ·1975 | ·0021 |
| 185 | 33·1997 | ·2018 | ·2039 | ·2060 | ·2081 | ·2102 | ·2123 | ·2144 | ·2165 | ·2186 | ·0021 |
| 186 | 33·2207 | ·2228 | ·2249 | ·2270 | ·2291 | ·2312 | ·2333 | ·2353 | ·2374 | ·2395 | ·0021 |
| 187 | 33·2416 | ·2437 | ·2457 | ·2478 | ·2499 | ·2520 | ·2540 | ·2561 | ·2582 | ·2602 | ·0021 |
| 188 | 33·2623 | ·2643 | ·2664 | ·2685 | ·2705 | ·2726 | ·2746 | ·2767 | ·2787 | ·2808 | ·0021 |
| 189 | 33·2828 | ·2848 | ·2869 | ·2889 | ·2909 | ·2930 | ·2950 | ·2970 | ·2991 | ·3011 | ·0020 |
| 190 | 33·3031 | ·3051 | ·3072 | ·3092 | ·3112 | ·3132 | ·3152 | ·3172 | ·3192 | ·3212 | ·0020 |
| 191 | 33·3233 | ·3253 | ·3273 | ·3293 | ·3313 | ·3333 | ·3353 | ·3372 | ·3392 | ·3412 | ·0020 |
| 192 | 33·3432 | ·3452 | ·3472 | ·3492 | ·3511 | ·3531 | ·3551 | ·3571 | ·3590 | ·3610 | ·0020 |
| 193 | 33·3630 | ·3649 | ·3669 | ·3689 | ·3708 | ·3728 | ·3747 | ·3767 | ·3786 | ·3806 | ·0020 |
| 194 | 33·3825 | ·3845 | ·3864 | ·3884 | ·3903 | .3922 | ·3942 | ·3961 | ·3980 | ·4000 | ·0019 |
| 195 | 33·4019 | ·4038 | ·4057 | ·4077 | ·4096 | ·4115 | ·4134 | ·4153 | ·4172 | ·4192 | ·0019 |
| 196 | 33·4211 | ·4230 | ·4249 | .4268 | ·4287 | ·4306 | ·4325 | ·4344 | ·4362 | ·4381 | ·0019 |
| 197 | 33·4400 | ·4419 | ·4438 | ·4457 | ·4476 | ·4494 | ·4513 | ·4532 | ·4550 | ·4569 | ·0019 |
| 198 | 33·4588 | ·4606 | ·4625 | ·4644 | ·4662 | ·4681 | ·4699 | ·4718 | ·4736 | ·4755 | ·0019 |

TABLE IV. $\frac{d^2}{w} t = T_V - T_v$—(*continued*).

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. |
| 199 | 33·4773 | ·4791 | ·4810 | ·4828 | ·4846 | ·4865 | ·4883 | ·4901 | ·4920 | ·4938 | ·0018 |
| 200 | 33·4956 | ·4974 | ·4992 | ·5010 | ·5028 | ·5047 | ·5065 | ·5083 | ·5101 | ·5119 | ·0018 |
| 201 | 33·5137 | ·5155 | ·5172 | ·5190 | ·5208 | ·5226 | ·5244 | ·5262 | ·5280 | ·5297 | ·0018 |
| 202 | 33·5315 | ·5333 | ·5351 | ·5368 | ·5386 | ·5404 | ·5421 | ·5439 | ·5456 | ·5474 | ·0018 |
| 203 | 33·5492 | ·5509 | ·5527 | ·5544 | ·5561 | ·5579 | ·5596 | ·5614 | ·5631 | ·5648 | ·0017 |
| 204 | 33·5666 | ·5683 | ·5700 | ·5717 | ·5735 | ·5752 | ·5769 | ·5786 | ·5803 | ·5820 | ·0017 |
| 205 | 33·5837 | ·5854 | ·5871 | ·5888 | ·5905 | ·5922 | ·5939 | ·5956 | ·5973 | ·5990 | ·0017 |
| 206 | 33·6007 | ·6024 | ·6040 | ·6057 | ·6074 | ·6091 | ·6107 | ·6124 | ·6141 | ·6157 | ·0017 |
| 207 | 33·6174 | ·6191 | ·6207 | ·6224 | ·6240 | ·6257 | ·6273 | ·6290 | ·6306 | ·6323 | ·0016 |
| 208 | 33·6339 | ·6355 | ·6372 | ·6388 | ·6404 | ·6420 | ·6437 | ·6453 | ·6469 | ·6485 | ·0016 |
| 209 | 33·6502 | ·6518 | ·6534 | ·6550 | ·6566 | ·6582 | ·6598 | ·6614 | ·6630 | ·6646 | ·0016 |
| 210 | 33·6662 | ·6678 | ·6694 | ·6710 | ·6726 | ·6741 | ·6757 | ·6773 | ·6789 | ·6805 | ·0016 |
| 211 | 33·6820 | ·6836 | ·6852 | ·6867 | ·6883 | ·6899 | ·6914 | ·6930 | ·6946 | ·6961 | ·0016 |
| 212 | 33·6977 | ·6992 | ·7008 | ·7023 | ·7039 | ·7054 | ·7070 | ·7085 | ·7100 | ·7116 | ·0015 |
| 213 | 33·7131 | ·7146 | ·7162 | ·7177 | ·7192 | ·7207 | ·7223 | ·7238 | ·7253 | ·7268 | ·0015 |
| 214 | 33·7283 | ·7298 | ·7313 | ·7329 | ·7344 | ·7359 | ·7374 | ·7389 | ·7404 | ·7419 | ·0015 |
| 215 | 33·7434 | ·7448 | ·7463 | ·7478 | ·7493 | ·7508 | ·7523 | ·7538 | ·7552 | ·7567 | ·0015 |
| 216 | 33·7582 | ·7597 | ·7612 | ·7626 | ·7641 | ·7656 | ·7670 | ·7685 | ·7700 | ·7714 | ·0015 |
| 217 | 33·7729 | ·7743 | ·7758 | ·7772 | ·7787 | ·7801 | ·7816 | ·7830 | ·7845 | ·7859 | ·0014 |
| 218 | 33·7874 | ·7888 | ·7902 | ·7917 | ·7931 | ·7945 | ·7960 | ·7976 | ·7988 | ·8002 | ·0014 |
| 219 | 33·8016 | ·8031 | ·8045 | ·8059 | ·8073 | ·8087 | ·8101 | ·8115 | ·8129 | ·8144 | ·0014 |
| 220 | 33·8158 | ·8172 | ·8186 | ·8200 | ·8214 | ·8227 | ·8241 | ·8255 | ·8269 | ·8283 | ·0014 |
| 221 | 33·8297 | ·8311 | ·8325 | ·8338 | ·8352 | ·8366 | ·8380 | ·8394 | ·8407 | ·8421 | ·0014 |
| 222 | 33·8435 | ·8448 | ·8462 | ·8476 | ·8489 | ·8503 | ·8517 | ·8530 | ·8544 | ·8557 | ·0014 |
| 223 | 33·8571 | ·8584 | ·8598 | ·8611 | ·8625 | ·8638 | ·8651 | ·8665 | ·8678 | ·8692 | ·0013 |
| 224 | 33·8705 | ·8718 | ·8732 | ·8745 | ·8758 | ·8772 | ·8785 | ·8798 | ·8811 | ·8824 | ·0013 |
| 225 | 33·8838 | ·8851 | ·8864 | ·8877 | ·8890 | ·8903 | ·8916 | ·8930 | ·8943 | ·8956 | ·0013 |
| 226 | 33·8969 | ·8982 | ·8995 | ·9008 | ·9021 | ·9034 | ·9046 | ·9059 | ·9072 | ·9085 | ·0013 |
| 227 | 33·9098 | ·9111 | ·9124 | ·9136 | ·9149 | ·9162 | ·9175 | ·9187 | ·9200 | ·9213 | ·0013 |
| 228 | 33·9226 | ·9238 | ·9251 | ·9264 | ·9276 | ·9289 | ·9301 | ·9314 | ·9326 | ·9339 | ·0013 |
| 229 | 33·9351 | ·9364 | ·9376 | ·9389 | ·9401 | ·9414 | ·9426 | ·9439 | ·9451 | ·9463 | ·0012 |
| 230 | 33·9476 | ·9488 | ·9500 | ·9513 | ·9525 | ·9537 | ·9550 | ·9562 | ·9574 | ·9586 | ·0012 |
| 231 | 33·9598 | ·9611 | ·9623 | ·9635 | ·9647 | ·9659 | ·9671 | ·9683 | ·9695 | ·9707 | ·0012 |
| 232 | 33·9719 | ·9732 | ·9744 | ·9756 | ·9768 | ·9779 | ·9791 | ·9803 | ·9815 | ·9827 | ·0012 |
| 233 | 33·9839 | ·9851 | ·9863 | ·9875 | ·9886 | ·9898 | ·9910 | ·9922 | ·9934 | ·9945 | ·0012 |
| 234 | 33·9957 | ·9969 | ·9981 | ·9992 | ·0004 | ·0016 | ·0027 | ·0039 | ·0050 | ·0062 | ·0012 |
| 235 | 34·0074 | ·0085 | ·0097 | ·0108 | ·0120 | ·0131 | ·0143 | ·0154 | ·0166 | ·0177 | ·0012 |
| 236 | 34·0189 | ·0200 | ·0212 | ·0223 | ·0234 | ·0246 | ·0257 | ·0268 | ·0280 | ·0291 | ·0011 |
| 237 | 34·0302 | ·0314 | ·0325 | ·0336 | ·0347 | ·0359 | ·0370 | ·0381 | ·0392 | ·0403 | ·0011 |
| 238 | 34·0414 | ·0426 | ·0437 | ·0448 | ·0459 | ·0470 | ·0481 | ·0492 | ·0503 | ·0514 | ·0011 |
| 239 | 34·9525 | ·0536 | ·0547 | ·0558 | ·0569 | ·0580 | ·0591 | ·0602 | ·0613 | ·0624 | ·0011 |
| 240 | 34·0635 | ·0645 | ·0656 | ·0667 | ·0678 | ·0689 | ·0700 | ·0710 | ·0721 | ·0732 | ·0011 |
| 241 | 34·0743 | ·0753 | ·0764 | ·0775 | ·0785 | ·0796 | ·0807 | ·0817 | ·0828 | ·0839 | ·0011 |
| 242 | 34·0849 | ·0860 | ·0870 | ·0881 | ·0892 | ·0902 | ·0913 | ·0923 | ·0934 | ·0944 | ·0011 |
| 243 | 34·0955 | ·0965 | ·0975 | ·0986 | ·0996 | ·1007 | ·1017 | ·1028 | ·1038 | ·1048 | ·0010 |
| 244 | 34·1059 | ·1069 | ·1079 | ·1090 | ·1100 | ·1110 | ·1120 | ·1131 | ·1141 | ·1151 | ·0010 |
| 245 | 34·1161 | ·1172 | ·1182 | ·1192 | ·1202 | ·1212 | ·1223 | ·1233 | ·1243 | ·1253 | ·0010 |
| 246 | 34·1263 | ·1273 | ·1283 | ·1293 | ·1303 | ·1313 | ·1323 | ·1333 | ·1343 | ·1353 | ·0010 |
| 247 | 34·1363 | ·1373 | ·1383 | ·1393 | ·1403 | ·1413 | ·1423 | ·1433 | ·1443 | ·1453 | ·0010 |
| 248 | 34·1463 | ·1472 | ·1482 | ·1492 | ·1502 | ·1512 | ·1521 | ·1531 | ·1541 | ·1551 | ·0010 |
| 249 | 34·1560 | ·1570 | ·1580 | ·1590 | ·1599 | ·1609 | ·1619 | ·1628 | ·1638 | ·1648 | ·0010 |

## Table V.

### Inclination and Velocity Table. $\frac{d^2}{w} D = D_V - D_v$.*

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. |
| 40 | 0 | ·4838 | ·9640 | 1·4407 | 1·9137 | 2·3830 | 2·8488 | 3·3110 | 3·7689 | 4·2240 |
| 41 | 4·6757 | 5·1240 | 5·5688 | 6·0101 | 6·4482 | 6·8828 | 7·3141 | 7·7421 | 8·1660 | 8·5874 |
| 42 | 9·0056 | 9·4207 | 9·8327 | 10·2410 | 10·6467 | 11·0496 | 11·4494 | 11·8462 | 12·2397 | 12·6306 |
| 43 | 13·0187 | 13·4039 | 13·7862 | 14·1652 | 14·5419 | 14·9159 | 15·2872 | 15·6557 | 16·0211 | 16·3843 |
| 44 | 16·7450 | 17·1030 | 17·4585 | 17·8110 | 18·1614 | 18·5094 | 18·8549 | 19·1980 | 19·5383 | 19·8766 |
| 45 | 20·2125 | 20·5460 | 20·8772 | 21·2054 | 21·5320 | 21·8565 | 22·1788 | 22·4989 | 22·8169 | 23·1327 |
| 46 | 23·4463 | 23·7578 | 24·0671 | 24·3736 | 24·6788 | 24·9821 | 25·2834 | 25·5827 | 25·8801 | 26·1756 |
| 47 | 26·4691 | 26·7607 | 27·0503 | 27·3376 | 27·6234 | 27·9075 | 28·1897 | 28·4702 | 28·7486 | 29·0254 |
| 48 | 29·3006 | 29·5739 | 29·8455 | 30·1151 | 30·3833 | 30·6498 | 30·9147 | 31·1779 | 31·4393 | 31·6993 |
| 49 | 31·9576 | 32·2143 | 32·4695 | 32·7227 | 32·9747 | 33·2253 | 33·4743 | 33·7219 | 33·9679 | 34·2125 |
| 50 | 34·4557 | 34·6973 | 34·9375 | 35·1761 | 35·4134 | 35·6493 | 35·8837 | 36·1167 | 36·3480 | 36·5783 |
| 51 | 36·8073 | 37·0349 | 37·2613 | 37·4862 | 37·7099 | 37·9323 | 38·1534 | 38·3731 | 38·5914 | 38·8086 |
| 52 | 39·0246 | 39·2394 | 39·4529 | 39·6651 | 39·8762 | 40·0860 | 40·2947 | 40·5022 | 40·7083 | 40·9135 |
| 53 | 41·1175 | 41·3204 | 41·5221 | 41·7225 | 41·9221 | 42·1205 | 42·3179 | 42·5142 | 42·7095 | 42·9037 |
| 54 | 43·0967 | 43·2887 | 43·4795 | 43·6690 | 43·8578 | 44·0456 | 44·2324 | 44·4182 | 44·6031 | 44·7870 |
| 55 | 44·9698 | 45·1516 | 45·3325 | 45·5122 | 45·6910 | 45·8689 | 46·0457 | 46·2217 | 46·3964 | 46·5705 |
| 56 | 46·7437 | 46·9160 | 47·0874 | 47·2581 | 47·4277 | 47·5965 | 47·7644 | 47·9314 | 48·0973 | 48·2625 |
| 57 | 48·4270 | 48·5906 | 48·7534 | 48·9153 | 49·0764 | 49·2368 | 49·3963 | 49·5551 | 49·7130 | 49·8701 |
| 58 | 50·0265 | 50·1822 | 50·3370 | 50·4909 | 50·6442 | 50·7968 | 50·9487 | 51·0999 | 51·2505 | 51·4002 |
| 59 | 51·5492 | 51·6975 | 51·8451 | 51·9917 | 52·1378 | 52·2832 | 52·4280 | 52·5721 | 52·7155 | 52·8583 |
| 60 | 53·0003 | 53·1417 | 53·2825 | 53·4224 | 53·5618 | 53·7005 | 53·8386 | 53·9761 | 54·1130 | 54·2492 |
| 61 | 54·3847 | 54·5196 | 54·6539 | 54·7875 | 54·9205 | 55·0529 | 55·1846 | 55·3158 | 55·4462 | 55·5761 |
| 62 | 55·7054 | 55·8342 | 55·9623 | 56·0899 | 56·2169 | 56·3433 | 56·4690 | 56·5942 | 56·7188 | 56·8428 |
| 63 | 56·9663 | 57·0891 | 57·2114 | 57·3330 | 57·4542 | 57·5749 | 57·6950 | 57·8146 | 57·9338 | 58·0523 |
| 64 | 58·1703 | 58·2878 | 58·4046 | 58·5209 | 58·6367 | 58·7521 | 58·8669 | 58·9832 | 59·0949 | 59·2081 |
| 65 | 59·3209 | 59·4332 | 59·5449 | 59·6562 | 59·7669 | 59·8772 | 59·9869 | 60·0961 | 60·2047 | 60·3130 |
| 66 | 60·4207 | 60·5280 | 60·6348 | 60·7411 | 60·8470 | 60·9523 | 61·0572 | 61·1616 | 61·2654 | 61·3688 |
| 67 | 61·4719 | 61·5744 | 61·6766 | 61·7783 | 61·8796 | 61·9804 | 62·0808 | 62·1807 | 62·2802 | 62·3793 |
| 68 | 62·4779 | 62·5761 | 62·6739 | 62·7711 | 62·8680 | 62·9646 | 63·0607 | 63·1565 | 63·2519 | 63·3468 |
| 69 | 63·4414 | 63·5356 | 63·6294 | 63·7227 | 63·8157 | 63·9084 | 64·0006 | 64·0924 | 64·1838 | 64·2749 |
| 70 | 64·3656 | 64·4559 | 64·5459 | 64·6356 | 64·7249 | 64·8137 | 64·9022 | 64·9903 | 65·0779 | 65·1652 |
| 71 | 65·2522 | 65·3388 | 65·4250 | 65·5107 | 65·5962 | 65·6813 | 65·7660 | 65·8504 | 65·9345 | 66·0182 |
| 72 | 66·1015 | 66·1845 | 66·2671 | 66·3494 | 66·4313 | 66·5128 | 66·5940 | 66·6749 | 66·7553 | 66·8355 |
| 73 | 66·9153 | 66·9949 | 67·0740 | 67·1529 | 67·2314 | 67·3096 | 67·3875 | 67·4649 | 67·5422 | 67·6190 |
| 74 | 67·6955 | 67·7717 | 67·8476 | 67·9231 | 67·9983 | 68·0733 | 68·1479 | 68·2223 | 68·2964 | 68·3702 |
| 75 | 68·4436 | 68·5168 | 68·5896 | 68·6620 | 68·7342 | 68·8062 | 68·8778 | 68·9492 | 69·0204 | 69·0912 |
| 76 | 69·1617 | 69·2318 | 69·3017 | 69·3712 | 69·4404 | 69·5094 | 69·5780 | 69·6464 | 69·7145 | 69·7823 |
| 77 | 69·8497 | 69·9169 | 69·9838 | 70·0503 | 70·1166 | 70·1826 | 70·2483 | 70·3137 | 70·3787 | 70·4436 |
| 78 | 70·5082 | 70·5725 | 70·6365 | 70·7004 | 70·7639 | 70·8271 | 70·8901 | 70·9527 | 71·0149 | 71·0770 |
| 79 | 71·1388 | 71·2004 | 71·2617 | 71·3228 | 71·3837 | 71·4442 | 71·5045 | 71·5646 | 71·6244 | 71·6839 |
| 80 | 71·7432 | 71·8023 | 71·8611 | 71·9196 | 71·9779 | 72·0359 | 72·0937 | 72·1513 | 72·2086 | 72·2656 |
| 81 | 72·3225 | 72·3791 | 72·4354 | 72·4915 | 72·5473 | 72·6030 | 72·6584 | 72·7135 | 72·7685 | 72·8232 |
| 82 | 72·8776 | 72·9317 | 72·9856 | 73·0393 | 73·0927 | 73·1458 | 73·1988 | 73·2514 | 73·3038 | 73·3560 |
| 83 | 73·4079 | 73·4596 | 73·5111 | 73·5622 | 73·6132 | 73·6639 | 73·7145 | 73·7648 | 73·8149 | 73·8647 |
| 84 | 73·9143 | 73·9636 | 74·0127 | 74·0615 | 74·1101 | 74·1585 | 74·2067 | 74·2546 | 74·3023 | 74·3498 |
| 85 | 74·3971 | 74·4441 | 74·4910 | 74·5376 | 74·5839 | 74·6301 | 74·6760 | 74·7217 | 74·7670 | 74·8123 |
| 86 | 74·8573 | 74·9022 | 74·9468 | 74·9912 | 75·0355 | 75·0795 | 75·1233 | 75·1669 | 75·2104 | 75·2536 |
| 87 | 75·2966 | 75·3395 | 75·3821 | 75·4246 | 75·4668 | 75·5089 | 75·5507 | 75·5924 | 75·6339 | 75·6752 |
| 88 | 75·7163 | 75·7572 | 75·7980 | 75·8385 | 75·8788 | 75·9190 | 75·9590 | 75·9988 | 76·0384 | 76·0778 |
| 89 | 76·1171 | 76·1562 | 76·1952 | 76·2339 | 76·2725 | 76·3109 | 76·3492 | 76·3873 | 76·4252 | 76·4629 |
| 90 | 76·5005 | 76·5379 | 76·5751 | 76·6121 | 76·6490 | 76·6857 | 76·7223 | 76·7588 | 76·7951 | 76·8312 |

* Calculated from the formula of W. D. Niven, Esq., M.A.

## TABLE V. $\frac{d^2}{w} D = D_V - D_v$ —(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. |
| 91 | 76·8671 | 76·9029 | 76·9385 | 76·9739 | 77·0092 | 77·0444 | 77·0794 | 77·1142 | 77·1489 | 77·1835 |
| 92 | 77·2179 | 77·2522 | 77·2863 | 77·3203 | 77·3541 | 77·3878 | 77·4213 | 77·4547 | 77·4879 | 77·5210 |
| 93 | 77.5540 | 77·5868 | 77·6195 | 77·6520 | 77·6844 | 77·7167 | 77·7488 | 77·7807 | 77·8125 | 77·8442 |
| 94 | 77·8757 | 77·9071 | 77·9384 | 77·9695 | 78·0005 | 78·0314 | 78·0622 | 78·0929 | 78·1234 | 78·1538 |
| 95 | 78·1841 | 78·2142 | 78·2442 | 78·2741 | 78·3039 | 78·3335 | 78·3630 | 78·3924 | 78·4216 | 78·4508 |
| 96 | 78·4798 | 78·5087 | 78·5375 | 78·5662 | 78·5947 | 78·6231 | 78·6514 | 78·6796 | 78·7076 | 78·7356 |
| 97 | 78·7634 | 78·7911 | 78·8188 | 78·8463 | 78·8736 | 78·9009 | 78·9280 | 78·9551 | 78·9819 | 79·0087 |
| 98 | 79·0354 | 79·0621 | 79·0886 | 79·1150 | 79·1413 | 79·1675 | 79·1936 | 79·2195 | 79·2454 | 79·2712 |
| 99 | 79·2968 | 79·3224 | 79·3478 | 79·3731 | 79·3983 | 79·4234 | 79·4484 | 79·4731 | 79·4982 | 79·5230 |
| 100 | 79·5476 | 78·5722 | 79·5966 | 79·6210 | 79·6453 | 79·6695 | 79·6935 | 79·7175 | 79·7414 | 79·7652 |
| 101 | 79·7889 | 79·8124 | 79·8359 | 79·8593 | 79·8826 | 79·9058 | 79·9289 | 79·9519 | 79·9748 | 79·9976 |
| 102 | 80·0203 | 80·0430 | 80·0655 | 80·0879 | 80·1102 | 80·1324 | 80·1544 | 80·1763 | 80·1981 | 80·2197 |
| 103 | 80·2412 | 80·2625 | 80·2837 | 80·3048 | 80·3256 | 80·3462 | 80·3667 | 80·3869 | 80·4071 | 80·4270 |
| 104 | 80·4466 | 80·4661 | 80·4854 | 80·5045 | 80·5234 | 80·5420 | 80·5605 | 80·5787 | 80·5967 | 80·6145 |
| 105 | 80·6321 | 80·6495 | 80·6667 | 80·6835 | 80·7003 | 80·7169 | 80·7333 | 80·7495 | 80·7654 | 80·7813 |
| 106 | 80·7970 | 80·8126 | 80·8280 | 80·8432 | 80·8583 | 80·8733 | 80·8882 | 80·9029 | 80·9175 | 80·9319 |
| 107 | 80·9463 | 80·9606 | 80·9747 | 80·9886 | 81·0026 | 81·0164 | 81·0301 | 81·0437 | 81·0573 | 81·0707 |
| 108 | 81·0841 | 81·0973 | 81·1105 | 81·1236 | 81·1366 | 81·1495 | 81·1624 | 81·1751 | 81·1877 | 81·2003 |
| 109 | 81·2129 | 81·2253 | 81·2377 | 81·2501 | 81·2623 | 81·2745 | 81·2866 | 81·2986 | 81·3105 | 81·3224 |
| 110 | 81·3342 | 81·3460 | 81·3578 | 81·3695 | 81·3811 | 81·3927 | 81·4042 | 81·4156 | 81·4269 | 81·4382 |
| 111 | 81·4495 | 81·4607 | 81·4719 | 81·4829 | 81·4939 | 81·5049 | 81·5159 | 81·5268 | 81·5377 | 81·5485 |
| 112 | 81·5593 | 81·5700 | 81·5807 | 81·5913 | 81·6019 | 81·6124 | 81·6230 | 81·6334 | 81·6439 | 81·6543 |
| 113 | 81·6647 | 81·6750 | 81·6853 | 81·6955 | 81·7057 | 81·7159 | 81·7260 | 81·7361 | 81·7462 | 81·7562 |
| 114 | 81·7662 | 81·7761 | 81·7861 | 81·7960 | 81·8058 | 81·8156 | 81·8254 | 81·8351 | 81·8448 | 81·8545 |
| 115 | 81·8641 | 81·8737 | 81·8833 | 81·8929 | 81·9024 | 81·9119 | 81·9213 | 81·9307 | 81·9401 | 81·9495 |
| 116 | 81·9588 | 81·9681 | 81·9774 | 81·9866 | 81·9958 | 82·0049 | 82·0141 | 82·0232 | 82·0322 | 82·0413 |
| 117 | 82·0503 | 82·0592 | 82·0682 | 82·0771 | 82·0860 | 82·0948 | 82·1036 | 82·1124 | 82·1212 | 82·1299 |
| 118 | 82·1386 | 82·1473 | 82·1559 | 82·1645 | 82·1731 | 82·1817 | 82·1902 | 82·1988 | 82·2073 | 82·2157 |
| 119 | 82·2241 | 82·2325 | 82·2408 | 82·2492 | 82·2575 | 82·2657 | 82·2740 | 82·2822 | 82·2903 | 82·2985 |
| 120 | 82·3066 | 82·3147 | 82·3228 | 82·3309 | 82·3389 | 82·3469 | 82·3549 | 82·3629 | 82·3708 | 82·3787 |
| 121 | 82·3865 | 82·3944 | 82·4022 | 82·4100 | 82·4178 | 82·4255 | 82·4333 | 82·4410 | 82·4486 | 82·4563 |
| 122 | 82·4639 | 82·4715 | 82·4790 | 82·4865 | 82·4940 | 82·5015 | 82·5090 | 82·5164 | 82·5238 | 82·5312 |
| 123 | 82·5386 | 82·5459 | 82·5533 | 82·5606 | 82·5679 | 82·5751 | 82·5824 | 82·5896 | 82·5968 | 82·6040 |
| 124 | 82·6112 | 82·6183 | 82·6254 | 82·6324 | 82·6395 | 82·6465 | 82·6535 | 82·6605 | 82·6675 | 82·6744 |
| 125 | 82·6814 | 82·6883 | 82·6951 | 82·7019 | 82·7088 | 82·7156 | 82·7224 | 82·7291 | 82·7359 | 82·7427 |
| 126 | 82·7494 | 82·7561 | 82·7627 | 82·7694 | 82·7760 | 82·7826 | 82·7892 | 82·7957 | 82·8023 | 82·8088 |
| 127 | 82·8153 | 82·8218 | 82·8283 | 82·8348 | 82·8412 | 82·8477 | 82·8541 | 82·8604 | 82·8668 | 82·8731 |
| 128 | 82·8794 | 82·8857 | 82·8920 | 82·8983 | 82·9045 | 82·9107 | 82·9169 | 82·9231 | 82·9292 | 82·9354 |
| 129 | 82·9415 | 82·9477 | 82·9538 | 82·9599 | 82·9660 | 82·9720 | 82·9780 | 82·9840 | 82·9900 | 82·9960 |
| 130 | 83·0019 | 83·0079 | 83·0138 | 83·0197 | 83·0256 | 83·0315 | 83·0373 | 83·0432 | 83·0490 | 83·0548 |
| 131 | 83·0606 | 83·0664 | 83·0721 | 83·0779 | 83·0836 | 83·0893 | 83·0950 | 83·1007 | 83·1063 | 83·1119 |
| 132 | 83·1176 | 83·1232 | 83·1288 | 83·1344 | 83·1400 | 83·1455 | 83·1511 | 83·1566 | 83·1621 | 83·1676 |
| 133 | 83·1730 | 83·1785 | 83·1840 | 83·1894 | 83·1949 | 83·2003 | 83·2057 | 83·2110 | 83·2164 | 83·2217 |
| 134 | 83·2271 | 83·2324 | 83·2377 | 83·2430 | 83·2483 | 83·2536 | 83·2588 | 83·2641 | 83·2693 | 83·2745 |
| 135 | 83·2797 | 83·2849 | 83·2900 | 83·2951 | 83·3003 | 83·3054 | 83·3105 | 83·3156 | 83·3207 | 83·3257 |
| 136 | 83·3308 | 83·3359 | 83·3409 | 83·3459 | 83·3509 | 83·3560 | 83·3609 | 83·3659 | 83·3709 | 83·3759 |
| 137 | 83·3808 | 83·3857 | 83·3906 | 83·3955 | 83·4004 | 83·4053 | 83·4101 | 83·4150 | 83·4198 | 83·4247 |
| 138 | 83·4295 | 83·4343 | 83·4391 | 83·4438 | 83·4486 | 83·4533 | 83·4581 | 83·4628 | 83·4676 | 83·4723 |
| 139 | 83·4770 | 83·4817 | 83·4863 | 83·4910 | 83·4956 | 83·5003 | 83·5049 | 83·5095 | 83·5141 | 83·5187 |
| 140 | 83·5233 | 83·5279 | 83·5325 | 83·5371 | 83·5417 | 83·5462 | 83·5507 | 83·5553 | 83·5598 | 83·5642 |
| 141 | 83·5687 | 83·5732 | 83·5777 | 83·5821 | 83·5866 | 83·5910 | 83·5954 | 83·5999 | 83·6043 | 83·6087 |
| 142 | 83·6130 | 83·6174 | 83·6218 | 83·6261 | 83·6305 | 83·6348 | 83·6392 | 83·6435 | 83·6478 | 83·6522 |
| 143 | 83·6565 | 83·6607 | 83·6650 | 83·6693 | 83·6735 | 83·6778 | 83·6820 | 83·6862 | 83·6904 | 83·6946 |
| 144 | 83·6988 | 83·7030 | 83·7072 | 83·7114 | 83·7156 | 83·7197 | 83·7239 | 83·7280 | 83·7321 | 83·7362 |

## TABLE V. $\frac{d^2}{w}D = D_V - D_v$—(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. |
| 145 | 83·7403 | 83·7444 | 83·7485 | 83·7526 | 83·7567 | 83·7608 | 83·7649 | 83·7689 | 83·7730 | 83·7770 |
| 146 | 83·7810 | 83·7850 | 83·7891 | 83·7930 | 83·7970 | 83·8010 | 83·8050 | 83·8090 | 83·8130 | 83·8170 |
| 147 | 83·8209 | 83·8249 | 83·8288 | 83·8327 | 83·8366 | 83·8406 | 83·8445 | 83·8484 | 83·8522 | 83·8561 |
| 148 | 83·8600 | 83·8639 | 83 8677 | 83·8715 | 83·8754 | 83·8792 | 83·8830 | 83·8869 | 83·8907 | 83·8945 |
| 149 | 83·8983 | 83·9021 | 83·9059 | 83·9096 | 83 9134 | 83·9172 | 83·9209 | 83·9247 | 83·9285 | 83·9322 |
| 150 | 83·9359 | 83·9396 | 83·9433 | 83·9470 | 83·9507 | 83·9544 | 83·9581 | 83·9617 | 83·9654 | 83·9691 |
| 151 | 83·9727 | 83·9764 | 83·9800 | 83·9837 | 83·9873 | 83·9909 | 83·9946 | 83·9982 | 84·0018 | 84·0054 |
| 152 | 84·0090 | 84·0126 | 84·0161 | 84·0197 | 84·0233 | 84·0269 | 84·0304 | 84·0340 | 84·0375 | 84·0410 |
| 153 | 84·0446 | 84·0481 | 84·0516 | 84·0551 | 84·0587 | 84·0622 | 84·0657 | 84·0692 | 84·0727 | 84·0762 |
| 154 | 84·0796 | 84·0831 | 84·0866 | 84·0900 | 84·0935 | 84 0969 | 84·1004 | 84·1038 | 84·1072 | 84·1106 |
| 155 | 84·1140 | 84·1174 | 84·1208 | 84·1242 | 84·1276 | 84·1310 | 84·1344 | 84·1378 | 84·1412 | 84·1445 |
| 156 | 84·1479 | 84·1513 | 84·1546 | 84·1579 | 84·1613 | 84·1646 | 84·1679 | 84·1713 | 84·1746 | 84·1779 |
| 157 | 84·1812 | 84·1845 | 84 1878 | 84·1911 | 84·1943 | 84·1976 | 84·2009 | 84·2041 | 84·2074 | 84·2107 |
| 158 | 84·2139 | 84·2172 | 84·2204 | 84·2237 | 84·2269 | 84·2301 | 84·2333 | 84·2366 | 84·2398 | 84·2430 |
| 159 | 84·2461 | 84·2493 | 84·2525 | 84·2557 | 84·2588 | 84 2620 | 84·2652 | 84·2683 | 84·2715 | 84·2746 |
| 160 | 84·2778 | 84·2809 | 84·2840 | 84·2871 | 84·2902 | 84·2933 | 84 2965 | 84·2996 | 84·3027 | 84·3058 |
| 161 | 84·3088 | 84·3119 | 84·3150 | 84·3180 | 84·3210 | 84·3242 | 84·3272 | 84·3302 | 84·3333 | 84·3363 |
| 162 | 84·3394 | 84·3424 | 84·3454 | 84 3484 | 84·3514 | 84·3544 | 84·3574 | 84·3604 | 84·3634 | 84·3664 |
| 163 | 84·3694 | 84·3724 | 84·3753 | 84·3783 | 84·3813 | 84·3843 | 84·3872 | 84·3902 | 84·3931 | 84·3960 |
| 164 | 84·3990 | 84·4019 | 84 4048 | 84·4078 | 84·4107 | 84·4136 | 84·4165 | 84·4194 | 84·4223 | 84·4252 |
| 165 | 84·4281 | 84·4310 | 84·4339 | 84·4367 | 84·4396 | 84·4425 | 84·4453 | 84·4482 | 84·4510 | 84·4539 |
| 166 | 84·4567 | 84·4596 | 84·4624 | 84·4652 | 84·4680 | 84·4709 | 84·4737 | 84·4765 | 84·4793 | 84·4821 |
| 167 | 84·4849 | 84·4877 | 84·4905 | 84·4933 | 84·4961 | 84·4988 | 84·5016 | 84·5044 | 84·5070 | 84·5099 |
| 168 | 84·5127 | 84·5154 | 84·5181 | 84·5209 | 84·5236 | 84·5263 | 84·5291 | 84·5318 | 84·5345 | 84·5372 |
| 169 | 84·5399 | 84·5426 | 84·5453 | 84·5480 | 84·5508 | 84·5534 | 84·5561 | 84·5588 | 84·5615 | 84·5641 |
| 170 | 84·5668 | 84·5695 | 84·5721 | 84·5748 | 84·5775 | 84·5801 | 84·5828 | 84·5854 | 84·5880 | 84·5907 |
| 171 | 84·5933 | 84·5959 | 84·5985 | 84·6012 | 84·6038 | 84·6064 | 84·6090 | 84·6116 | 84·6142 | 84·6168 |
| 172 | 84·6193 | 84·6219 | 84·6245 | 84·6271 | 84·6297 | 84·6322 | 84·6348 | 84·6373 | 84·6399 | 84·6424 |
| 173 | 84·6449 | 84·6475 | 84·6500 | 84·6525 | 84·6550 | 84·6575 | 84·6601 | 84·6626 | 84·6651 | 84·6676 |
| 174 | 84·6701 | 84·6726 | 84·6750 | 84·6776 | 84·6800 | 84·6825 | 84·6850 | 84·6875 | 84·6899 | 84·6924 |
| 175 | 84·6948 | 84·6973 | 84·6997 | 84·7022 | 84·7046 | 84·7071 | 84·7095 | 84·7119 | 84·7144 | 84·7168 |
| 176 | 84·7192 | 84·7216 | 84·7240 | 84·7264 | 84·7288 | 84·7312 | 84·7336 | 84·7360 | 84·7384 | 84·7408 |
| 177 | 84·7432 | 84·7455 | 84·7479 | 84·7503 | 84·7526 | 84·7550 | 84·7574 | 84·7597 | 84·7621 | 84·7645 |
| 178 | 84·7668 | 84·7692 | 84·7715 | 84·7739 | 84·7762 | 84·7785 | 84·7809 | 84·7832 | 84·7855 | 84·7878 |
| 179 | 84·7902 | 84·7925 | 84·7948 | 84·7972 | 84·7994 | 84·8017 | 84·8040 | 84·8063 | 84·8086 | 84·8109 |
| 180 | 84 8131 | 84·8154 | 84·8177 | 84·8199 | 84·8222 | 84·8244 | 84·8267 | 84·8289 | 84·8312 | 84·8334 |
| 181 | 84 8357 | 84·8379 | 84·8401 | 84·8424 | 84·8446 | 84·8468 | 84·8490 | 84·8513 | 84·8535 | 84·8557 |
| 182 | 84·8579 | 84·8601 | 84·8623 | 84·8645 | 84·8667 | 84·8689 | 84·8711 | 84·8732 | 84·8754 | 84·8776 |
| 183 | 84·8798 | 84·8819 | 84·8841 | 84·8863 | 84·8884 | 84·8906 | 84·8927 | 84·8949 | 84·8970 | 84·8992 |
| 184 | 84·9013 | 84·9035 | 84·9056 | 84·9077 | 84 9099 | 84·9120 | 84·9141 | 84 9162 | 84·9184 | 84·9205 |
| 185 | 84·9226 | 84·9247 | 84·9268 | 84·9289 | 84·9310 | 84·9331 | 84·9351 | 84·9372 | 84·9393 | 84·9414 |
| 186 | 84·9435 | 84·9456 | 84·9476 | 94·9497 | 84·9518 | 84·9538 | 84·9559 | 84·9580 | 84·9600 | 84·9621 |
| 187 | 84·9641 | 84·9662 | 84·9682 | 84·9702 | 84·9723 | 84·9743 | 84·9763 | 84·9784 | 84·9804 | 84·9824 |
| 188 | 84·9845 | 84·9865 | 84·9885 | 84·9905 | 84·9925 | 84·9946 | 84·9966 | 84·9986 | 85·0006 | 85·0026 |
| 189 | 85·0045 | 85·0065 | 85·0085 | 85·0105 | 85·0125 | 85·0145 | 85·0165 | 85·0185 | 85·0204 | 85·0224 |
| 190 | 85·0244 | 85·0263 | 85·0283 | 85·0303 | 85·0322 | 85·0342 | 85·0361 | 85·0380 | 85·0400 | 85·0419 |
| 191 | 85·0438 | 85·0458 | 85·0477 | 85·0496 | 85·0515 | 85·0535 | 85·0554 | 85·0573 | 85·0592 | 85·0611 |
| 192 | 85·0630 | 85·0650 | 85·0669 | 85·0687 | 85·0706 | 85·0725 | 85·0744 | 85·0763 | 85·0782 | 85·0801 |
| 193 | 85·0820 | 85·0838 | 85·0857 | 85·0876 | 85·0895 | 85·0913 | 85·0932 | 85·0951 | 85·0969 | 85·0988 |
| 194 | 85·1006 | 85·1025 | 85·1043 | 85·1062 | 85·1080 | 85·1099 | 85·1117 | 85·1136 | 85·1154 | 85·1172 |
| 195 | 85·1190 | 85·1208 | 85·1227 | 85·1245 | 85·1263 | 85·1281 | 85·1299 | 85·1317 | 85·1335 | 85·1353 |
| 196 | 85·1371 | 95·1389 | 95·1407 | 85·1425 | 85·1443 | 85·1460 | 85·1478 | 85·1496 | 85·1514 | 85·1531 |
| 197 | 85·1549 | 85·1567 | 85·1584 | 85·1602 | 85·1619 | 85·1637 | 85·1654 | 85·1672 | 85·1689 | 85·1707 |
| 198 | 85·1724 | 85·1741 | 85·1759 | 85·1776 | 85·1793 | 85·1810 | 85·1827 | 85·1844 | 85·1862 | 85·1879 |

TABLE V. $\frac{d^2}{w}D=D_V-D_v$—(*continued*).

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. | degs. |
| 199 | 85·1896 | 85·1913 | 85·1930 | 85·1947 | 85·1964 | 85·1981 | 85·1998 | 85·2014 | 85·2031 | 85·2048 |
| 200 | 85·2065 | 85·2081 | 85·2098 | 85·2115 | 85·2131 | 85·2148 | 85·2165 | 85·2181 | 85·2198 | 85·2214 |
| 201 | 85·2231 | 85·2247 | 85·2264 | 85·2280 | 85·2296 | 85·2313 | 85·2329 | 85·2346 | 85·2362 | 85·2378 |
| 202 | 85·2394 | 85·2411 | 85·2427 | 85·2443 | 85·2459 | 85·2476 | 85·2492 | 85·2507 | 85·2524 | 85·2540 |
| 203 | 85·2556 | 85·2572 | 85·2588 | 85·2604 | 85·2620 | 85·2635 | 85·2651 | 85·2667 | 85·2682 | 85·2698 |
| 204 | 85·2714 | 85·2729 | 85·2745 | 85·2760 | 85·2776 | 85·2791 | 85·2807 | 85·2822 | 85·2838 | 85·2853 |
| 205 | 85·2868 | 85·2884 | 85·2899 | 85·2915 | 85·2930 | 85·2945 | 85·2960 | 85·2975 | 85·2990 | 85·3005 |
| 206 | 85·3020 | 85·3035 | 85·3051 | 85·3066 | 85·3081 | 85·3095 | 85·3110 | 85·3125 | 85·3140 | 85·3155 |
| 207 | 85·3170 | 85·3184 | 85·3199 | 85·3214 | 85·3229 | 85·3244 | 85·3258 | 85·3273 | 85·3287 | 85·3302 |
| 208 | 85·3316 | 85·3331 | 85·3345 | 85·3360 | 85·3373 | 85·3388 | 85·3403 | 85·3417 | 85·3431 | 85·3446 |
| 209 | 85·3460 | 85·3474 | 85·3488 | 85·3503 | 85·3517 | 85·3531 | 85·3545 | 85·3559 | 85·3573 | 85·3587 |
| 210 | 85·3601 | 85·3615 | 85·3629 | 85·3643 | 85·3657 | 85·3671 | 85·3685 | 85·3698 | 85·3712 | 85·3726 |
| 211 | 85·3740 | 85·3754 | 85·3767 | 85·3781 | 85·3795 | 85·3808 | 85·3822 | 85·3836 | 85·3849 | 85·3863 |
| 212 | 85·3876 | 85·3890 | 85·3903 | 85·3917 | 85·3930 | 85·3943 | 85·3957 | 85·3970 | 85·3983 | 85·3996 |
| 213 | 85·4010 | 85·4023 | 85·4036 | 85·4049 | 85·4063 | 85·4076 | 85·4089 | 85·4102 | 85·4115 | 85·4128 |
| 214 | 85·4141 | 85·4154 | 85·4167 | 85·4180 | 85·4193 | 85·4206 | 85·4219 | 85·4232 | 85·4245 | 85·4258 |
| 215 | 85·4271 | 85·4284 | 85·4297 | 85·4309 | 85·4322 | 85·4335 | 85·4348 | 85·4360 | 85·4373 | 85·4385 |
| 216 | 85·4398 | 85·4411 | 85·4423 | 85·4436 | 85·4448 | 85·4461 | 85·4473 | 85·4485 | 85·4498 | 85·4510 |
| 217 | 85·4523 | 85·4535 | 85·4547 | 85·4560 | 85·4572 | 85·4584 | 85·4597 | 85·4609 | 85·4621 | 85·4633 |
| 218 | 85·4645 | 85·4658 | 85·4670 | 85·4682 | 85·4694 | 85·4706 | 85·4718 | 85·4730 | 85·4742 | 85·4754 |
| 219 | 85·4766 | 85·4778 | 85·4790 | 85·4802 | 85·4814 | 85·4825 | 85·4837 | 85·4849 | 85·4861 | 85·4873 |
| 220 | 85·4885 | 85·4896 | 85·4908 | 85·4920 | 85·4932 | 85·4943 | 85·4955 | 85·4967 | 85·4978 | 85·4990 |
| 221 | 85·5001 | 85·5013 | 85·5024 | 85·5036 | 85·5047 | 85·5059 | 85·5070 | 85·5082 | 85·5093 | 85·5105 |
| 222 | 85·5116 | 85·5128 | 85·5139 | 85·5150 | 85·5162 | 85·5173 | 85·5184 | 85·5195 | 85·5207 | 85·5218 |
| 223 | 85·5229 | 85·5240 | 85·5251 | 85·5262 | 85·5273 | 85·5285 | 85·5296 | 85·5307 | 85·5318 | 85·5329 |
| 224 | 85·5340 | 85·5351 | 85·5362 | 85·5373 | 85·5384 | 85·5394 | 85·5405 | 85·5416 | 85·5427 | 85·5438 |
| 225 | 85·5449 | 85·5460 | 85·5470 | 85·5481 | 85·5492 | 85·5502 | 85·5513 | 85·5524 | 85·5534 | 85·5545 |
| 226 | 85·5556 | 85·5566 | 85·5577 | 85·5588 | 85·5598 | 85·5609 | 85·5619 | 85·5630 | 85·5640 | 85·5651 |
| 227 | 85·5661 | 85·5672 | 85·5682 | 85·5693 | 85·5703 | 85·5713 | 85·5724 | 85·5734 | 85·5744 | 85·5755 |
| 228 | 85·5765 | 85·5775 | 85·5785 | 85·5796 | 85·5806 | 85·5816 | 85·5826 | 85·5836 | 85·5846 | 85·5856 |
| 229 | 85·5866 | 85·5876 | 85·5886 | 85·5896 | 85·5906 | 85·5916 | 85·5926 | 85·5936 | 85·5946 | 85·5956 |
| 230 | 85·5966 | 85·5976 | 85·5986 | 85·5996 | 85·6006 | 85·6015 | 85·6025 | 85·6035 | 85·6045 | 85·6055 |
| 231 | 85·6064 | 85·6074 | 85·6084 | 85·6094 | 85·6103 | 85·6113 | 85·6123 | 85·6132 | 85·6142 | 85·6151 |
| 232 | 85·6161 | 85·6171 | 85·6180 | 85·6190 | 85·6199 | 85·6209 | 85·6218 | 85·6228 | 85·6237 | 85·6247 |
| 233 | 85·6256 | 85·6265 | 85·6275 | 85·6284 | 85·6294 | 85·6303 | 85·6312 | 85·6321 | 85·6331 | 85·6340 |
| 234 | 85·6349 | 85·6358 | 85·6367 | 85·6377 | 85·6386 | 85·6395 | 85·6404 | 85·6413 | 85·6422 | 85·6431 |
| 235 | 85·6441 | 85·6450 | 85·6459 | 85·6468 | 85·6477 | 85·6486 | 85·6495 | 85·6504 | 85·6513 | 85·6522 |
| 236 | 85·6531 | 85·6540 | 85·6549 | 85·6558 | 85·6566 | 85·6575 | 85·6584 | 85·6593 | 85·6602 | 85·6611 |
| 237 | 85·6619 | 85·6628 | 85·6637 | 85·6646 | 85·6654 | 85·6663 | 85·6672 | 85·6680 | 85·6689 | 85·6698 |
| 238 | 85·6706 | 85·6715 | 85·6724 | 85·6732 | 85·6741 | 85·6749 | 85·6758 | 85·6766 | 85·6775 | 85·6783 |
| 239 | 85·6792 | 85·6800 | 85·6809 | 85·6817 | 85·6826 | 85·6834 | 85·6843 | 85·6851 | 85·6859 | 85·6868 |
| 240 | 85·6876 | 85·6885 | 85·6893 | 85·6901 | 85·6909 | 85·6918 | 85·6926 | 85·6934 | 85·6942 | 85·6951 |
| 241 | 85·6959 | 85·6967 | 85·6975 | 85·6984 | 85·6992 | 85·7000 | 85·7008 | 85·7016 | 85·7024 | 85·7032 |
| 242 | 85·7041 | 85·7049 | 85·7057 | 85·7065 | 85·7073 | 85·7081 | 85·7089 | 85·7097 | 85·7105 | 85·7113 |
| 243 | 85·7121 | 85·7128 | 85·7136 | 85·7144 | 85·7152 | 85·7160 | 85·7168 | 85·7176 | 85·7184 | 85·7192 |
| 244 | 85·7200 | 85·7207 | 85·7215 | 85·7223 | 85·7231 | 85·7239 | 85·7246 | 85·7254 | 85·7262 | 85·7270 |
| 245 | 85·7277 | 85·7285 | 85·7293 | 85·7301 | 85·7308 | 85·7316 | 85·7324 | 85·7331 | 85·7339 | 85·7346 |
| 246 | 85·7354 | 85·7362 | 85·7369 | 85·7377 | 85·7384 | 85·7392 | 85·7399 | 85·7407 | 85·7414 | 85·7422 |
| 247 | 85·7429 | 85·7436 | 85·7444 | 85·7451 | 85·7459 | 85·7466 | 85·7474 | 85·7481 | 85·7488 | 55·7496 |
| 248 | 85·7503 | 85·7510 | 85·7517 | 85·7525 | 85·7532 | 85·7539 | 85·7547 | 85·7554 | 85·7561 | 85·7568 |
| 249 | 85·7575 | 85·7583 | 85·7590 | 85·7597 | 85·7604 | 85·7611 | 85·7618 | 85·7626 | 85·7633 | 85·7640 |

N.B.—See later Tables in Appendix, page 507.

# CHAPTER VI.

## ROTATION AND RIFLING.

### ROTATION.

### *Object of Rotating a Projectile.*

**Advantages of rifling.**

The advantages of rotating a projectile are:

1. Increased accuracy.
2. The power of using an elongated projectile.

**Accuracy.**

Inaccuracy in a S.B. gun is due to the shot leaving the gun rotating on an accidental axis. Whatever the cause of this may be, the effect is to produce an uneven and accidental distribution of the resistance of the air over the surface of the projectile giving rise to accidental deviations. With a rifled gun, any change in the resistance due to the rotation of the projectile is constant, and the corresponding deflection can therefore be allowed for.

**Use of elongated projectile.**

An elongated projectile can be used, as it can be given "spin" on its longer axis by means of the twist of the rifling. If the projectile did not spin, it would, on leaving the gun, have a tendency to immediately turn over and rotate on its shorter axis, and thus its flight would be most inaccurate, and its range limited. Sufficient spin must, therefore, be given to ensure its travelling approximately *point first* throughout the entire range. The advantage of an elongated projectile in retaining its velocity is explained on p. 119.

For instance, the muzzle velocity of a 400 lb. projectile fired from the service 10″ R.M.L. gun is 1,364 feet per second, the charge of powder being 70 lbs. Now, at 2,000 yards range, the projectile will have a remaining velocity of 1,120 feet, while, at that range, a spherical solid shot of the same *weight* would have a velocity of 854 feet, and a spherical solid shot of the same *calibre* would have a velocity of 742 feet only. This presumes all the three projectiles to start with the same muzzle velocity; but the instance will serve to show how the velocity is kept up in the case of the elongated projectile.

Rifling a gun does not *necessarily* entail the use of elongated projectiles; but the collateral advantages attained by their use are so important that they are universally used. Some of the advantages so attained have been mentioned; but it will be

advisable to briefly recapitulate them here, and mention a few others not noted above.

Summary of advantages.

1. A diminished surface is offered for the resistance of the air to act upon, and thus greater range and greater power at a given range are obtained.
2. The trajectory is flatter; and thus the probability of hitting an object is increased.
3. The head may be of any required form or weight; as in the case of Palliser and Shrapnel shell.
4. By varying the length, different kinds of projectiles for the same gun can be brought to the same weight; and thus complications in range tables, &c. are avoided.
5. On the other hand, if desirable, a specially heavy (or light) projectile may be fired; as in the case of the 7″ and 7-pr. double shell.
6. The capacity of the projectile for powder or bullets is increased.

Besides the above, there are two advantages common to all rifled projectiles, whether elongated or not, viz.:—

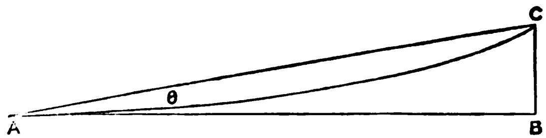
Percussion fuzes are more simple, as it is only necessary to provide for their action in one direction; and in the case of Shrapnel the bursting charge can be kept behind the bullets.*

*Rotation given.*

Definition of twist.

Rotation is given to a projectile by causing projections attached to it to travel along grooves inclined at an angle to the axis of the gun. The amount of this inclination, when the grooves are developed on a plane as shown in fig. 1, is termed the *twist* of the rifling.

Fig 1.




Thus, if AB represents the distance a shot would have to travel along the bore, or in continuation of the same, with a given twist or inclination of groove, while it made one complete revolution round its own axis, and BC at right angles to it, represent the space passed through by any point of the surface of the projectile during the time of its making this

* It would seem from recent experiments at Elswick that there is not much advantage in this latter.

complete revolution, then AC will represent the length of spiral due to such twist, and would show the length of a groove in the case of a gun long enough to allow of the projectile making a complete turn in the bore.

Twist is usually estimated in this manner, and is measured by the number of calibres in which one turn would be completed. For twist of service guns see table p. 272.

BC equals in length the circumference of the bore $= 2\pi r = \pi d$ if $d$ be the calibre or diameter of bore, while $AB = n\,d$, if $n$ be the number of calibres in which a complete turn is made.

**Angle of rifling.**

The angle $CAB = \theta$, is usually termed the angle of rifling.

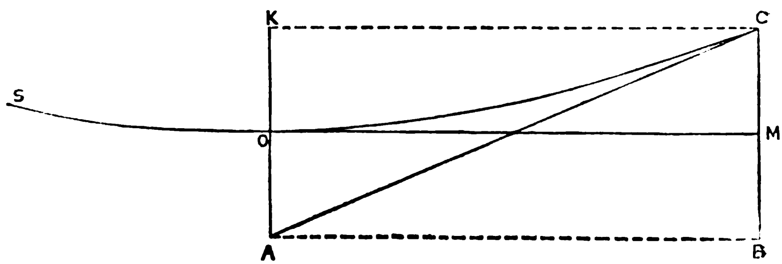
$$\text{Now, } \tan\theta = \frac{CB}{AB} = \frac{\pi d}{nd} = \frac{\pi}{n}$$

For example, take the 7-inch gun, whose spiral is one turn in 35 calibres, then

$$\tan\theta = \frac{\pi}{35} = \cdot 0897\,;\ \therefore \theta = 5^\circ\ 8' \text{ nearly.}$$

The *twist* may be either uniform or increasing; in the former case the inclination of the groove is always the same as shown by the plain line in fig. 1; in the latter the inclination increases, and a groove of such rifling would, when laid out, be some such curved line as shown by the line AC.

Fig. 2.




The form of this curve may correspond to the locus of any suitable equation; we ourselves generally use a parabolic curve where the equation is $x^2 = py$, and in which the increments of inclination are uniform—*Vide fig. 2.

**Velocity of rotation.**

The *velocity of rotation* of a projectile is usually measured by its *angular* velocity in units of circular measure per

* In the 80-ton gun, however, the curve used is the semicubical parabola, the equation to which is $x^{\frac{3}{2}} = p.y$

Angular velocity.

second. The angular velocity of a projectile making *one turn* in one second is $2\pi$.

Now, if $\omega$ be the angular velocity of a projectile per second, and $s$ the *number of turns* it makes in a second, then

$$s = \frac{\omega}{2\pi}; \qquad\qquad (1)$$

*i.e.*, the number of revolutions per second is proportional to the *angular velocity*.

Also, if the projectile makes *one revolution* in $n$ calibres—*i.e.*, in $nd$ inches, where $d$ is the calibre of the gun in inches, and $V$ the muzzle velociety in feet per second—then the number of revolutions of the projectile per second as it leaves the muzzle of the gun is

$$s = \frac{12V}{nd}*; \qquad\qquad (2)$$

Equating (1) and (2), it will be seen that

$$\omega = \frac{24\pi V}{nd}; \qquad\qquad (3)$$

or the angular velocity of a projectile is directly proportional to the muzzle velocity, and inversely proportional to the length of twist, estimated at the muzzle.

The linear velocity of rotation of any point in a rotating projectile is the *product* of its angular velocity into the distance of that point from the axis of rotation; or if $\omega$ be the angular velocity, and $r$ the distance of the point from its axis of rotation in inches,

$$\text{linear velocity of rotation} = \omega r = \frac{2\pi Vr}{nd} \text{ in feet per second.}$$

*Velocity of Rotation required for Steadiness of Flight.*

Empirical state of this question.

A projectile in motion is said to be steady in its flight when it has only a motion of translation and of rotation round its longer axis. Nothing is known accurately as to the velocity of rotation required to give steadiness of flight to an elongated projectile. The matter is entirely in the empirical stage, so

---

* Thus with the 10-inch R.M.L., where

$$M\,V = 1364 \text{ f.s.}$$
$$n = 40$$
$$d = \frac{10}{12} \text{ feet.}$$

The shot on leaving the muzzle is making $\frac{1364 \times 12}{40 \times 10} = 40\frac{3}{4}$ turns per second.

that when a gun is designed, it is given that angle of rifling which previous experience has shown to be more or less effective.

It has been assumed by our artillerists that a projectile fired at a low velocity requires a quicker spin, and consquently a sharper twist than if fired at a high velocity; and twist has been given to service guns according to this assumption, *e.g.*, in our 8-inch M.L. guns where the muzzle velocity is 1,400 f.s., the twist given is 1 in 40 calibres at the muzzle; while with the 8-inch howitzer, having a low muzzle velocity of, say, 550 f.s., a twist of 1 in 16 calibres is given.

**Greenhill's investigations.**

An attempt has, however, been lately made to put the matter on a more accurate footing, Professor Greenhill having investigated the question on the supposition that the air is frictionless and incompressible.

The investigation is too mathematical to be introduced here, but will be found in R. A. I. Proc., Vol. X., No. 7, p. 586.

The results for a projectile of the form of a prolate spheroid are given in the following table, in which $\alpha - \gamma$ is a quantity depending upon the form of the shot.

TABLE calculated by Captain J. P. CUNDILL, R.A.

| Length of projectile in calibres — | $\alpha - \gamma$. | Minimum twist at muzzle of gun requisite to give steadiness of flight = 1 turn in $n$ calibres. | | |
|---|---|---|---|---|
| | | Cast-iron common shell. Cavity = (¼) vol. of shell, s.g. of iron 7·207. | Solid steel bullet, s.g. of steel 8·000. | Solid lead and tin bullets of similar composition to M.H. bullets, s.g. = 10·990. |
| | | Value of $n$. | Value of $n$. | Value of $n$. |
| 2·0 | ·49418 | 63·87 | 72·21 | 84·29 |
| 2·2 | ·54431 | 56·31 | 63·67 | 74·32 |
| 2·4 | ·58679 | 50·41 | 57·00 | 66·53 |
| 2·6 | ·62315 | 45·65 | 51·62 | 60·26 |
| 2·8 | ·65454 | 41·74 | 47·19 | 55·09 |
| 3·0 | ·68192 | 38·45 | 43·47 | 50·74 |
| 3·2 | ·70598 | 35·64 | 40·30 | 47·04 |
| 3·4 | ·72724 | 33·22 | 37·56 | 43·84 |
| 3·6 | ·74615 | 31·11 | 35·17 | 41·05 |
| 3·8 | ·76303 | 29·25 | 33·07 | 38·61 |
| 4·0 | ·77820 | 27·60 | 31·21 | 36·43 |

Palliser projectiles have not been considered separately, as they require less spin than common shell.

**Twist independent of velocity of translation.**

By this theory the spin required to keep a given projectile steady varies directly as the velocity of translation ($V$), while the angular velocity given, as we see by equation (3), also

varies directly as $V$, and consequently the twist required is independent of the velocity of translation.

This conclusion seems to be confirmed by the experience of foreign gunmakers, as very good results have been obtained from rifled mortars having a twist as low as 1 in 60.

To extend the theory to the case of a service projectile moving in air, which is compressible and not frictionless, a more accurate knowledge of the resistance of the air must be obtained.

Summary.

Speaking generally, the velocity of rotation required to keep a projectile steady in flight depends—

(1.) On the centreing, or otherwise, of the projectile as it leaves the bore.

(2.) On the effect of the resistance of the air which depends upon the velocity of translation.

(3.) On the position of the centre of gravity of the projectile.

(4.) On the length of the projectile in calibres.

(5.) On the distribution of the mass of the projectile.

Necessity of centreing.

If the projectile is centred as it leaves the bore, there will be no force tending to cause rotation round its shorter axis until gravity deflects the trajectory from the line of departure, and in this case the force is gradually applied, and in a constant direction, producing similar steady gyration;* but if the projectile be not centred, there will be at once on leaving the bore a force causing rotation round its shorter axis, acting in an uncertain direction, and producing dissimilar unsteady gyration. In order to keep this gyration small, it is necessary to give a higher velocity of rotation than would have been required if the projectile had been centred; so that the axis of the projectile may be kept as nearly as possible in the direction of motion of the centre of gravity of the projectile, or, in other words, tangential to the trajectory. If the velocity of rotation is not sufficient, the amount of the gyration will increase, and the projectile becomes unsteady, and wabbles in flight. In extreme cases the projectile will turn over; as, for instance, in long shell when fired with a low velocity.†

Resistance of the air.

The effect of the resistance of the air, and the point of application of that resistance on projectiles of different shapes, will next be considered.

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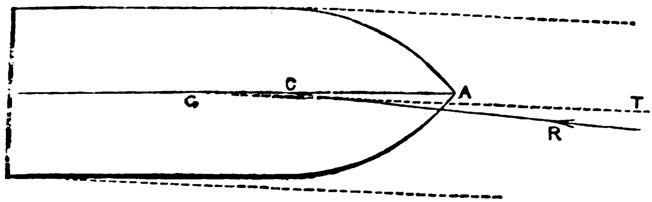
* Gyration must be understood to mean the rotation of the axis of the projectile itself round the trajectory described by its centre of gravity.

† When very low charges are used in high-angle firing, it is found that the projectile strikes the ground base first; with a little more charge, the projectile falls on its side; and with a still higher charge, the projectile strikes the ground nearly point first.—Sladen, p. 92.

Fig. 3.




Resistance of the air.

Fig. 3 represents a vertical projection of an ogival-headed projectile, $G$ the position of its centre of gravity in its longer axis, $GA$. The direction of motion of the projectile is represented by $GT$, being a tangent to the trajectory, which has dipped from the line of departure, which if the projectile is centred is coincident at the muzzle with the axis of the projectile, $GA$.

The front part of the projectile is, then, meeting the air in directions parallel to $GT$. The resultant of the resistance of the air opposed to this motion does not usually (owing to the form of head) act in exactly the opposite direction, but in a direction inclined to it, as $RC$. The point $C$, where the direction of the resultant of the resistance intersects the axis of the projectile, is called the "centre of resistance." The resultant $R$ acts in the direction $RC$ in the plane passing through the axis of the projectile and the tangent to the trajectory.

The resultant, $R$, acting at $C$ may be replaced by an equivalent force, $R$, acting at $G$, the centre of gravity of the projectile, and parallel to $RC$, and a couple whose moment is proportional to $R \times GC$. The tendency of the couple, as drawn in Fig. 1 (which represents the case of an ogival-headed projectile) is to *raise the point of the projectile—i.e.*, to give the projectile rotation round its shorter axis passing through its centre of gravity, and perpendicular to its longer axis.

**Gyration.**

The combination of this rotation and the rotation impressed on the projectile round its longer axis by the spiral grooves in the bore, gives rise to the gyration of the axis of the projectile round a tangent to its trajectory. If the moment of this couple is increased from any cause, the velocity of rotation of the projectile must also be proportionally increased, in order to keep the axis of the projectile as close to the trajectory as possible; or, in other words, to keep the amount of the gyration within moderate limits.

The magnitude of the resultant resistance for a projectile of given diameter depends principally on the velocity and

form of head of the projectile. Hence, when a projectile is fired with a high muzzle velocity, since the moment about the centre of gravity increases with the magnitude of the resultant resistance, a higher velocity of rotation is required to keep it steady under similar circumstances.

Flatheaded projectiles.

Flat-headed projectiles, for the same reason, require a higher velocity of rotation than ogival-headed projectiles. In experiments made by Colonel Owen, R.A., "on the derivation of elongated projectiles," it was found "that the velocity of "rotation given by the rifled B.L. 40 pr. was not sufficiently "high to keep a flat-headed shot steady during flight, except "at very short ranges."*

Position of C. of G.

The moment of the couple tending to produce rotation round the shorter axis, depends on the relative position of the centre of gravity and the centre of resistance—*i.e.*, on the distance *GC*, in Fig. 1. The greater this distance is, the greater will be the tendency to upset the projectile, and the greater must be the *velocity of rotation*, in order to keep the projectile steady in flight. If the centre of gravity of the projectile were purposely brought towards the base, the tendency of the projectile would be to fly base foremost, unless it were counteracted by a much greater velocity of rotation than would be necessary or desirable under service conditions. If, on the contrary, the centre of gravity is towards the head, this distance is smaller, and a lower velocity of rotation suffices to keep the projectile steady in flight; for instance, in the Snider bullet the centre of gravity is more towards the head than it would be if the bullet were solid, and the very low velocity of rotation imparted to it ensures tolerable accuracy of fire.

Length of projectile.

Generally speaking, the longer a projectile is in calibres for a given weight, the greater will be the velocity of rotation required to keep it steady in flight; because the resultant of the resistance usually acts with a greater leverage, *i.e.*, the moment of the couple tending to produce rotation is increased as the length of the projectile is increased. But it is quite possible, with some shapes of head and positions of centre of gravity, for the moment of the couple to be less with a longer projectile than with a shorter one of the same weight. In that case a greater velocity of rotation may be dispensed with. The principle to be remembered in considering the velocity of rotation to be given to an elongated projectile in order to keep it steady in flight is this—that the *velocity of rotation must be increased proportionately*

* *Vide* Owen's "Modern Artillery," p. 245.

*to the moment of the resultant resistance about the centre of gravity tending to rotate the projectile round its shorter axis.*

The rate of loss of velocity of rotation owing to the resistance of the air depends on the distribution of the mass of the projectile. The velocity of rotation is maintained longer in the case of an elongated shell than in that of an elongated shot of given weight. Hence it is found in practice that an elongated shell is steadier in flight than an elongated solid shot of the same weight; the reason being that the radius of gyration is longer in the shell, and for a given velocity of rotation the energy of rotation is greater. **Distribution of mass.**

## *Drift.*

The direction of the rotation given to all service elongated projectiles is "right-handed," *i.e.*, the upper part turns from left to right, with reference to an observer placed behind the gun. If the projectile is accurately centred, there will be no tendency to gyrate until gravity deflects the trajectory from the line of departure, and the direction of motion of the projectile ceases to be coincident with its axis. When this is the case, the resultant of the resistance of the air acts as in Fig. 3, tending (as explained before) to raise the point of the projectile, and to give it rotation round the shorter axis through the centre of gravity. The combination of these rotations causes the axis of the projectile to gyrate in a right-handed direction; and the resistance of the air acting on the left side of the projectile drives the projectile itself bodily towards the right, causing a permanent deflection. **Explanation of cause.**

This permanent deflection caused by the direction of the rifling is called drift.

The number of gyrations depends upon the velocity of the projectile: a projectile fired with a high velocity will make several gyrations, while a projectile fired with only a low velocity and at a high angle of elevation would only make a part of one gyration. **Gyrations depend upon velocity.**

In the above description of the spiral motion of an elongated ogival-headed projectile, the projectile has been supposed to be centred; but if this should not be the case gyration commences at once, and in an uncertain direction, and the axis of the projectile will be deflected at once, according to the position of the point on which the resultant of the resistance of the air acts on the projectile, and the projectile itself driven bodily in the same direction. Hence the shooting of guns **Effect of non-centring.**

Effect of non-centring.

in which the centring of the projectile is not secured cannot be relied upon for such accuracy as those guns in which the projectile is centred, because the drift cannot be so accurately allowed for.

Since the use of copper gas-checks in the 12·5-in. M.L. gun of 38 tons, the projectile has been centred, the mean drift to the right for a given range has increased, and the shooting has been more accurate.

Case of flat-headed projectile.

The drift of flat-headed projectiles* is not so marked as that of ogival-headed projectiles, and owing to the higher velocity of rotation required to keep flat-headed projectiles steady in flight, there is a difficulty in obtaining reliable experiments with flat-headed projectiles with service guns. Colonel Owen, R.A., made some experiments at Shoeburyness, in 1864, with flat-headed and cylindro-conoidal-headed shot fired from the Armstrong B.L. gun; and the conclusion drawn from them is "that the drift of cylindrical or flat-headed " projectiles is in the opposite direction to that of projectiles " with conoidal or pointed heads, fired with similar rotation. " For instance, if a cylindro-conoidal and a flat-headed shot " be both fired with right-handed rotation, the derivation of " the former will be to the right and the latter to the left."

There seems to be no doubt that flat-headed projectiles, for direct fire under service conditions with right-handed rotation, drift to the *left;* but for indirect and high-angle fire they may be driven to the right. It depends upon the direction of the rotation impressed on the projectile by the resultant of the resistance of the air.

It will be seen from the above how very complicated the question of the drift of elongated projectiles becomes, on account of the varying conditions of shape of head, steadiness of the projectile, &c.

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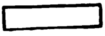
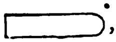
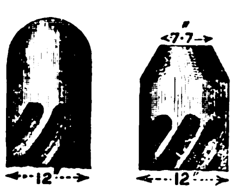
* By "flat-headed projectiles" are meant cylindrical-shaped projectiles  If the shoulder is rounded off, the centre of resistance may be in front of the centre of gravity , and the drift would be to the right.




This may be exemplified by the projectiles used in the Whitworth 35-ton gun and shown in the annexed drawing. Here though one is called a roundheaded, and the other a flatheaded shot, the drift is in both cases to the right.

The practical conclusions with regard to drift are:— **Practical conclusions.**

(1.) With service ogival-headed projectiles and right handed rotation, the drift is to the *right*.

(2.) With left-handed rotation, under similar conditions, the drift is to the *left*.

(3.) With flat-headed projectiles, the drift with right-handed rotation is generally to the *left*.

(4.) The sharper the twist of rifling the greater will the drift be.

**Permanent angle of deflection.** With guns having service rifling and projectiles, in order to compensate for the deflection of the projectile to the right, caused by the right-handed rifling, the tangent sight is in most cases inclined to the left. This inclination, which is called "the permanent angle of deflection," varies for the muzzle-loading natures according to the systems on which they are rifled.*

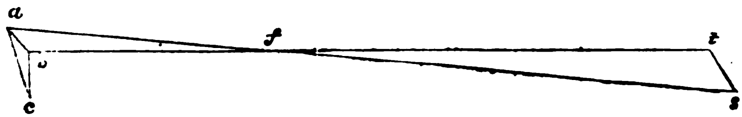
**How determined.** When a new nature of gun is about to be introduced, the permanent angle is calculated from actual practice at Shoeburyness with the specimen gun sent there on trial for range and accuracy. The gun is not sighted, but elevation is given by temporary means. A fine day being chosen for the practice, several rounds are fired with various elevations, and the angle is calculated for each round. The mean of the angles so obtained is adopted as the permanent angle of deflection.

**Calculation.** The formula used for determining the angle for each range is—

$$\tan. \theta = \frac{\text{deflection}}{\text{range}} \times \text{cosec elevation},$$

which is proved as follows:—

Let $b\ t$ represent the line of sight, the gun being laid straight on the target $t$, and let $t\ s$ be the deflection of the shot; now the line drawn from $s$—




through the foresight $f$, will give the point $a$, at which the head of the tangent sight $b\ c$ should be inclined to the left, so

* The actual amount for each nature of gun will be found in the Table, p. 272.

Permanent angle of deflection.

that the gun may be laid at the distance $t\,s$, to the left of the target. Having $a\,b$, the required angle $a\,c\,b$ is obtained. For as $a\,b\,f$, and $f\,t\,s$ are similar triangles—

$$\frac{f\,t}{t\,s} = \frac{b\,f}{a\,b};$$

but $b\,c$ being the length of the tangent scale, and $b\,f$ its radius—

$$b\,f = b\,c \times \text{cosec elevation, } b\,c\,f \text{ being a right angle.}$$

Again—

$$a\,b = b\,c, \text{ tangent } a\,c\,b,\ a\,b\,c \text{ being a right angle.}$$

$$\therefore \frac{f\,t}{t\,s} = \frac{\text{cosec elevation}}{\text{tan. } a\,c\,b};$$

$$\therefore \text{tan. } a\,c\,b = \frac{t\,s \text{ cosec elevation}}{f\,t}$$

but as angle $a\,c\,b$ is $\theta$, $t\,s$ the deflection, and $f\,t$ the range, the equation may be written as above—

$$\text{tan. } \theta = \frac{\text{deflection}}{\text{range}} \times \text{cosec elevation.}$$

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## Rifling.

### *Systems.*

The necessity of imparting rotation to an elongated projectile, and the great advantages of this latter form for gunnery purposes having been explained, the next point to consider is the system of rifling which should be adopted.

Object of rifling.

The object of any such system is to give the necessary amount of rotation or spin to the projectile with a minimum pressure on the bore of the piece, upon the grooves, and on the studs, ribs, soft coating, or otherwise of the projectile itself; the required result should also be obtained by the most simple means, and with the least possible loss of power.

The term "system of rifling" consists essentially in the means of giving rotation to the projectile, but the twist of the grooves, the length, diameter, or form of the projectile must depend upon the purpose for which a gun is required, no matter upon what system it may be rifled.

Conditions to be fulfilled.

The conditions especially desirable in a system of rifling for ordnance are—

1. Accuracy of fire.
2. Simplicity and durability of both projectile and gun.

3. Non-liability of projectile to jam in the bore either in loading or firing. **Conditions to be fulfilled.**
4. Must not bring too great a strain on either projectile or gun.

Not only must the system of rifling adopted give sufficient velocity of rotation to ensure stability of flight, but the projectile should also be as far as possible centred as it leaves the gun, *i.e.*, it should be rotating round its longest axis, and that axis should be coincident with the line of flight. As will be seen further on various modes of obtaining such centring have been tried, certain forms of groove, &c. being employed.

**Classification of systems.** Many plans have been brought forward, but most of the systems of rifling that have been adopted for guns may be divided into the following classes:—

1. M.L. or B.L. guns having projectiles of hard metal fitting the peculiar form of the bore mechanically.
2. M.L. or B.L. guns with projectiles having soft metal studs or ribs to fit the grooves.
3. M.L. or B.L. guns with projectiles having a soft metal envelope or cup which is expanded by the gas in the bore.

B.L. guns with projectiles having a soft metal coating or rings, larger in diameter than the bore, but which is compressed by the gas into the form of the bore.

**Whitworth.** Of the first class the Whitworth may be taken as the type. The Whitworth gun has a hexagonal spiral bore, the corners of which are rounded off.

The projectile is made of iron or steel, without studs or coating of any kind, and is fitted accurately to correspond with the bore.

The advantages of these systems are the simplicity and durability of the projectile.

The objections are, that both projectile and bore being hard fracture of one or the other is liable to occur from a shot jamming; that unless the bore be made of very hard material, it will rapidly be worn at the angles by the friction on it of the hard projectiles; and that the projectiles have to be accurately turned and are very expensive.

**Studded.** The French studded and Woolwich systems may be taken as examples of the second class.

In both these systems, which are nearly alike, the bore is rifled with a few deep grooves, and rotation is imparted to the projectile by means of soft metal studs which are fitted to correspond with the grooves.

Details as to the amount of twist. size of grooves, &c. will be given further on.

Disadvantages attached to first and second class.

The disadvantages of these systems are that the studs cause additional expense in manufacture, and are liable to injury; there is not sufficient bearing surface in the edges of the studs, which causes them to wear when fired, thus riding up the edges of the grooves, and bringing a great strain on the gun. The latter is also weakened by the deep grooves, and the projectile by the studs.

Both the first and second class are also liable to two grave defects, owing to the necessity of allowing a certain amount of play between the hard surfaces of the bore and the projectile.

This entails, firstly, the non-centring of the projectile, which tends to irregularity of shooting.*

Devices to obtain centring.

A device was adopted by Sir W. Armstrong with a view to centring the projectile, by which the projectile was made to enter easily, but in coming out was forced to ride up on inclined grooves so as to be accurately centred. The details of this arrangement will be given further on.

In some guns an attempt was made by giving a less inclination to the side of the grooves on which the stud in coming out of the bore presses (called the driving edge) than on the other (called the loading edge), to cause the studs to rise up on the grooves and thus to centre the projectile.

Both these plans were partially successful, but they bring a severe and wedging strain on the gun.

Windage.

Secondly, when the projectile lies in the bore of the gun there will be a space between it and the bore, which will be largest over the top of the projectile.

When the gun is fired there will be a rush of gas past the projectile, and this is objectionable for two reasons, viz., the waste of power, and the injury done to the bore by the violent passage of the extremely heated gas.

Scoring.

This injury is called scoring and is very serious, even when the bore of the gun is made of a hard and durable material like steel.

The adoption of gas-checks prevents this scoring, but they are only used in combination with studs as a makeshift, as they properly belong to the third class of systems, and their general adoption will naturally involve a change of groove, and the abolition of studs.

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* *See* p. 152.

In the third class there are various systems, such as Britten's, Parrott's, &c., the particulars of which may be seen by reference to works on gunnery. Britten, Woolwich polygroove.

As an example may be taken the new Woolwich polygroove system.

Here the projectile has no studs and is rotated by means of an expanding disc of copper attached to the base of the shot and driven by the explosion into a large number of shallow grooves in the bore.

This system has given such good results, that it has already been adopted in several new natures of ordnance, and may be said at present to have superseded the old Woolwich system of a few deep grooves and studs.

Sir W. Armstrong, in his new B. L. guns, has adopted a *similar* system; all these systems are, however, liable to the same objection with regard to non-centring as the first and second class. Armstrong new B.L. guns.

The projectile though centred in rear is not so in front, and being of hard metal throughout (with the exception of the base) must be allowed some play between it and the bore.

The advantages of this plan over the second class are— Advantages.

1st. Absence of windage.
2nd. The bore of the gun is less weakened by a number of shallow than by a few deep grooves.
3rd. The projectile is not weakened by the stud holes.
4th. Having no studs it is not so liable to injury.
5th. The total bearing surfaces of the grooves are larger, the number of grooves being so much greater.

The disadvantages are that the expanding base (called a gas-check) being liable to injury cannot, as a rule, be kept on the projectile, and that there is a difficulty as regards the ignition of time fuzes. Disadvantages.

The old Armstrong, Prussian, and French B.L. systems are examples of class four.

1. The original Armstrong gun has a polygroove bore, chambered for the charge and the projectile; the latter has a coating of lead attached by zinc solder, which is larger in diameter than the bore. The gas must therefore force this coating through the rifling of the bore. Original Armstrong.

This system is mentioned as being a familiar instance of this class, but may be considered obsolete.

The Prussian and French systems are very similar, and consist of one or more rings of soft metal round the projectile and slightly larger than the bore. These are compressed into the grooves by the gas. French and German.

In the earlier Prussian guns the rings are of lead and the grooves are what is termed wedge-shaped, *i.e.*, become smaller in breadth as they approach the muzzle, which increases the compression; but in the later patterns the rings are of copper and the grooves parallel.

Advantages and disadvantages.

The advantages of this class are—

1. There is no windage.
2. The projectile is accurately centred, except in some cases where there is only one ring and the windage is considerable over the front of the projectile.

The disadvantages are—

1. A percussion arrangement is required for the ignition of the fuze.
2. The projectile is weakened by the various means employed to attach the rings, except where the ring comes over the thick part of the base, as in the Elswick pattern, p. 357, which, though called a gas-check, belongs to this class.

*Pressures on Studs and Grooves.*

Pressure on studs, &c.

Important points to be considered with regard to a system of rifling are the pressures due to rifling upon the studs or other projecting parts by means of which the projectile is rotated in the bore, upon the grooves in the gun itself, and upon the walls of the bore.

The amount of these pressures can be determined exactly by a calculation, if the pressure developed upon discharge in the gun is known, as the former always bears a definite relation to the latter. With a uniform twist, the total pressure on the studs or gas-check, and so on the grooves of the gun, is a constant fraction of the pressure on the base of the shot, the value of the fraction depending on the angle of the rifling.

Great maximum pressure with uniform twist.

It is evident that with the uniform rifling there is a great pressure at first upon the grooves* or studs, which rapidly decreases towards the muzzle; this is owing to the fact that the angle of rifling is the same throughout, while the acceleration, as shown by the increments of velocity, is much the greatest to begin with, and falls away very quickly as the shot moves through the bore.

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* This is borne out practically by the greater wear which is found to occur in guns rifled with the uniform twist, in that part of the groove near the bottom of the bore. The Russians in their experimental field gun are using an increasing twist, as do the French also in their heavy guns, as well as in their new field gun, and for the reasons given in the text. Treatise on Gun Construction, p. 42.

With an increasing twist, however, the case is different for here the angle of rifling, which is nothing, or very small when the shot starts, increases rapidly, so that there is a much lower maximum pressure on the studs, but at the same time, a more uniform pressure. For example, in the case of two 10-inch guns, with a twist of 1 in 40 at the muzzle, the one rifled with a uniform, and the other with increasing twist, while the maximum pressure in the one case is 68 tons, coming down to 9 tons at the muzzle, in the other, where the increasing twist is used, the maximum pressure is reduced to one half, being only 36 tons, while the pressure is very uniform throughout.* Uniform pressure with increasing twist.

It has been found that the substitution of increasing for uniform rifling in the Woolwich guns, decreases the maximum pressure on the studs by about one-half, and where gas-checks are employed instead of studs this is a matter of considerable importance, as the surface which bears against the grooves is the same throughout.

Where, however, studs are employed to give the rotation, this is *not* the case, for as Mr. Longridge points out,† the *absolute* amount of pressure is not so important as the amount of pressure per unit of the bearing surface against which it is exerted. Application to studs.

Now it is evident from the nature of the rifling, when the twist is increasing, that the whole of the pressure exerted must at first be taken by one ring of studs, as the others do not come into bearing until the projectile is near the muzzle.

Thus, in the case of the 10-inch gun, quoted above, it may be easily seen that with two rings of studs, taking the bearing surface of one ring as the unit, the maximum pressure per unit is 34 tons, with an uniform, and 36 with an increasing twist; while with the 12-inch gun, whose projectile has three rings of studs, the gain of the uniform twist would be still greater.

In order to give rotation to a projectile, the pressure on the bore of the gun must be increased, for not only has the inertia of the shot to be overcome as to translation, but also as to rotation. Increased pressure due to rotation.

With guns rifled like our own this increment of pressure, however, as proved by Captain Noble, late R.A., is an exceedingly small one, though small as it is, he says that "it is

* Treatise on Gun Construction, p. 43.

† Paper "On the principles which should guide the construction of heavy ordnance, &c." Read at R.U.S. Institution, June 13, 1879.

Increased pressure due to rotation.

"still less in the parabolic than in the uniform system of "rifling."

His conclusions are borne out by the experiments of the Explosive Committee, who found no sensible differences of pressure in the 10-inch gun fired in the rifled and in the unrifled state.

It is clear that we may obtain a sufficient amount of rotation in the projectile, by the use of any one of the numerous systems of rifling which have been at various times proposed, and then we must choose that particular system which will give the rotation with least damage to bore of gun and projectile.

In 1863, at the time of introducing M.L. guns into the service, exhaustive trials were carried out with various systems of rifling brought forward by inventors, as well as by the official department, and the Woolwich system suited for studded projectiles and adapted from the French was adopted.

As was stated before, this is now giving way to what is styled the modern polygroove system, which in its essential form is one of those rejected in 1863.

### *Forms of Grooves.*

Grooves.

The next consideration will be the grooves; their size, shape, and number must depend upon the system of rifling adopted.

The depth of the grooves depends on the metal of which the driving rings, gas-checks, or studs are made. The harder and tougher this metal, the shallower the grooves can be made.

Shallow grooves weaken the bore less than deep ones, and the projectile having smaller projections meets with less resistance in its passage through the air.

Where gas-checks or driving rings are used the broader the groove the better hold it has, therefore the lands (or space between the grooves) should be as narrow as is consistent with strength.

The greater the number of grooves and the more gentle the twist, the narrower can be the lands, as the pressure on each driving edge is the less, and the motion of the projectile through the bore is more regular.

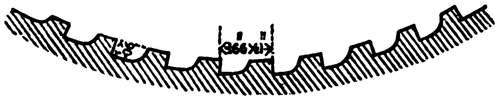
The form of groove should be as simple as possible; the simpler the form, and the less sharp the angles, the less the groove will suffer as a rule, and the less liable is the barrel to be split along the angle of the grooves.

The adoption of the system of studded projectiles rendered it necessary to employ deep grooves; but the introduction of gas-checks as a means of giving rotation has enabled a shallow form of groove to be used with the newer guns, this form having, as seen above, many advantages.

A description of some forms of groove will now be given.*

Service Armstrong.

With our service B.L. guns, in which lead-coated projectiles are forced through the bore, we have a great number of grooves and narrow lands, so that the lead coating is easily cut through. On account of the number of grooves these guns are said to have polygroove rifling, the form of the groove is very simple as shown below—



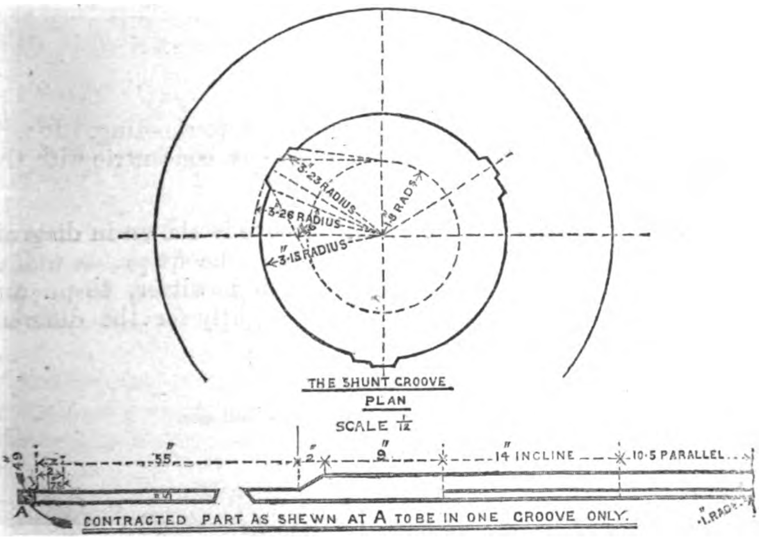
SECTION OF RIFLING (full size).

With the service M.L. guns using studded projectiles we employ five different forms of grooves as below.

Shunt.

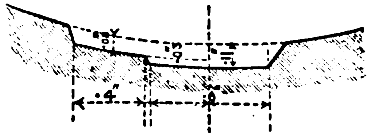
*(1.)* The "*shunt*" which is used with 64-pr. built up guns, Marks I., II., and III., which have not been retubed, and which have wrought-iron barrels.

PLAN OF MUZZLE SHOWING "SHUNT" GROOVES. Scale 3 ins. = 1 foot.




* Treatise on Gun Construction, p. 43.

Shunt.



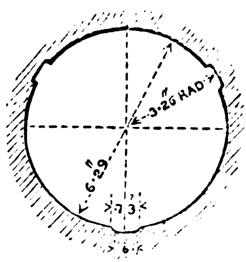
SECTION ON LINE A.B

FULL SIZE

The peculiarity in this system of rifling is that the depth and width of the grooves varies at different parts, the object aimed at being to provide a deep groove for the studs of the projectile to travel down when the gun is being loaded, and a shallow groove through which they must pass when the gun is fired, so that the projectile may be gripped and perfectly centred on leaving the muzzle. This system was abandoned as being complicated and liable to damage projectile and gun.

Plain.

Plain Groove. Scale ⅛th.




(2.) The "*plain groove.*"— This is really the narrow deep portion of the shunt groove.

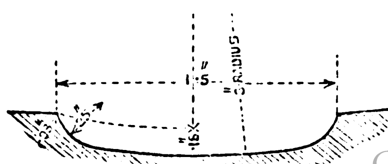
It is employed with all 64-prs., except those mentioned above as having the shunt grooves, so that they can all use the same ammunition.

This groove gives very good results as to shooting. It will be seen that the bottom of the groove is concentric with the bottom of the bore.

Woolwh.

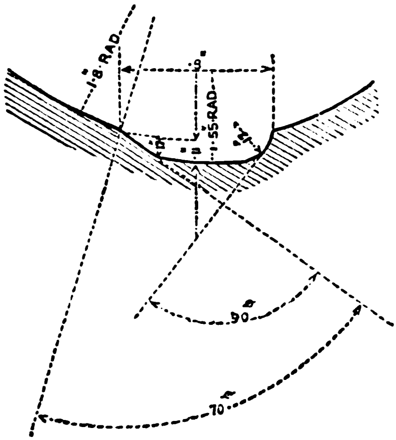
(3.) The so-called "*Woolwich*" groove is shown in diagram below, and is used with all guns above the 64-pr., as well as with the 80-pr. converted gun, 8-inch howitzer, 40-pr. and 25-pr. guns. The dimensions differ slightly for the different pieces, as will be seen in table at p. 272.

Woolwich Groove. Scale, full size.



(4.) The "*French modified*," with 16-prs. and 9-prs. R.M.L. guns, as shown in diagram below :— French modified.

SECTION OF GROOVE. Scale, full size.

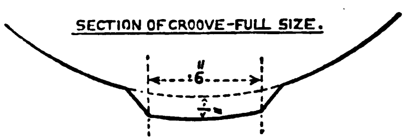



The driving edge of the groove forms an angle of 70° with the normal to the surface of the bore, and the loading side is at right angles to the driving side.

The width is 0″·8 at top, and the depth 0″·11, the corners being rounded off.

The smaller incline on the driving side is given in order that the studs may run up the incline, and thus be gripped and the projectile centred: the bottom of the grooves are eccentric with the bottom of the bore, so as to assist in this centring action.

(5.) The "*French*," with 7-pr. R.M.L. guns, as shown in diagram below :— French.


SECTION OF CROOVE—FULL SIZE.

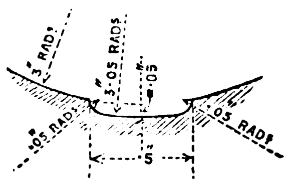
This rifling differs from the modified French system (used in the 9-pr. and 16-pr.) in not having the corners rounded and in the curve of the bottom of the groove being described

concentric to the bore. The grooves are 0″·6 wide at the bottom and 0″·1 deep.*

Polygroove.

The "*Modern Polygroove*" is shown in the following diagram:—

13-PR. R.M.L. GUN, 8 CWT. SECTION OF GROOVE. Full size.




This form of groove is used in conjunction with the driving gas-check.

In the 13-pr. it is 0″·5 in width and 0″·05 in depth, the bottom is concentric with the bore, and the edges are rounded.

In the 6″·3 howitzer the groove is 0″·5 in width and 0″·1 in depth.

The lands in these pieces are equal in width to the grooves.

So far this nature of groove has only been introduced for the two pieces given above, and the two experimental Howitzers, 8″ and 6″·6, but its use will be extended to 80-ton guns and other new pieces.

Mode of stopping projectiles.

With reference to the explanation given at p. , as to the necessity of having a constant space in rear of the projectile, or, in other words, a powder chamber of constant proportions, it is evident that the projectile must always be stopped at the same point in the bore by some mechanical contrivance, otherwise if the projectile is rammed home with varying strength, we should have the charge burnt with varying air space per pound of powder.

Two modes are employed with M.L. guns:—

1. Making use of the termination of the grooves themselves in conjunction with the studs on the shot, or the ribs on the gas-check.

This mode is employed in the case of the 40-pr. siege gun, the 8-inch and 6·3-inch service howitzers, and the two new experimental rifled howitzers. With these latter pieces, the

---

* With this nature of groove, and also with the plain groove, the width is measured at the bottom; the angles being rounded off in all other grooves the width at bottom cannot be accurately measured.

termination of the grooves is made very abrupt by doing away with the slope at the end of the grooves as far as possible. Mode of stopping projectile.

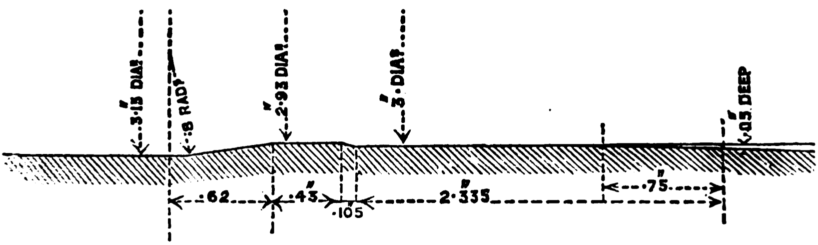
No doubt the use of this expedient will be further extended, and it will in all probability be employed in the 80-ton gun.

6·3-INCH R.M.L. HOWITZER 18 CWT. STOP FOR PROJECTILE. Full size.

2. By reducing the diameter of the bore immediately in front of the powder chamber, or, in other words, putting a choke in the bore which stops the gas-check attached to the shot when it is not furnished with ribs or projections.

This method has so far been adopted only with the new 13-pr. field guns. It cannot be applied to guns already made, while in many cases the mode first mentioned can be so utilised for such guns.

13-PR. R.M.L. GUN OF 8 CWT. STOP FOR PROJECTILE. Full size.




With B.L. guns the projectile is stopped by the commencement of the rifling.

# CHAPTER VII.

## ACCURACY OF FIRE.

### ERRORS WHEN THE GUN AND OBJECT ARE STATIONARY.

If the gun, projectile, charge, service, and all the details relating to the working of ordnance were perfect, and the atmosphere were always in exactly the same condition, the accuracy would also be perfect, that is, the projectile fired under similar circumstances would always strike in the same place.

Errors of fire. In practice, however, many disturbing elements interfere, and produce *errors of fire* of various descriptions.

In the most favourable circumstances these errors are reduced to a minimum, and under these conditions we can, as will be seen p. 179, calculate the chance of any gun hitting a given object.

In most cases of practice, however, the conditions are not so favourable as they are when the gun is tried for accuracy, and the errors of fire consequently increase; at sea a fresh error is also almost invariably introduced, arising from the motion of the gun platform, of the object, or both.

Errors due to:— When the distance and direction are constant, errors of fire are due principally to—

1. Variations in muzzle velocity.
2. Unsteadiness of the projectile as it leaves the bore, and during flight.
3. Variation of the projectiles in form, weight, or position of centre of gravity.
4. State of the atmosphere.
5. Personal error in laying, and visibility of target.
6. Inclination of trunnions to the horizon.
7. Unsteadiness of gun, carriage, and slide on firing.

Variations in M.V. (1.) It is essential, in order to obtain great accuracy of fire, to have the muzzle velocity as uniform as possible. Variations in muzzle velocity result from (*a.*) want of uniformity in the ignition and combustion of the charge, as explained in the chapter on powder. For instance, the degree of hardness in ramming home will cause a variation with those guns where there is not a special provision to stop the projectile at a fixed distance. (*b.*) Another cause of variations is the small difference in the weight of projectiles and charges. (*c.*) The state of the bore and of the studs or gas-check have a most important influence. (*d.*) The temperature of the gun produces a slight effect, owing to the absorption of heat by a cool gun.

From this cause the first round is usually short. (*e.*) The use of lubrication or of a very wet sponge, will often affect the muzzle velocity.

(2.) The unsteadiness of a projectile as it leaves the bore is one of the most important sources of errors of fire. It may result from accidental causes, such as the shearing of the studs, the breaking up of the gas-check, or from the contact of the body of the projectile with the lands of the bore, or it may become permanent, owing to wear or injuries of the bore. In the old Armstrong B.L. guns it may result from the lead coat stripping; but in M.L. guns it more commonly arises from insufficient velocity of rotation, or from non-centring due to the system of rifling employed. This unsteadiness causes greater loss of velocity during flight than when the axis is steady, since the projectile presents a greater surface to the resistance of the air, hence the range is diminished; also, since the drift is allowed for under normal conditions by the inclination of the tangent sights to the left, any unsteadiness of the projectile at the muzzle or during flight will cause a variation in the actual drift, which results in both lateral and vertical error. In the best modern B.L. guns this error is very small.

**Unsteadiness of projectile.**

(3.) This is not a usual source of error with rifled guns, as by careful manufacture the weights of projectiles are kept within very close limits, and the forms are similar.

(4.) The temperature, moisture, density, and motion of the atmosphere influence the accuracy of fire. The temperature and moisture affect the muzzle velocity, and therefore cause errors in range, whilst the density and motion affect the lateral error as well as the range.

**Variations in projectiles.**

The lateral deviation produced by wind must be allowed for in laying the gun. The deflection leaf on the tangent sight may be used in making allowance for error due to wind, and the gun should then be laid on the object.

**State of atmosphere.**

Formulæ have been given for calculating the error due to wind; but as the variability of wind in a long range, both in velocity and direction, is often considerable, no reliable results can be obtained by theory.

(5.) Errors in laying are incidental to all systems of firing, and may be reduced to a small quantity by careful and intelligent Nos. 1 when the object can be clearly seen. Constant practice at different ranges, and the use of the aiming target (page 430), is the only way of acquiring the necessary skill.

**Errors in laying.**

It is stated in the drill regulations for the Prussian artillery that a series of experiments were carried out to ascertain the effect of thoroughly instructing the men laying the guns.

Advantage of well-trained men.

At a range of 1,300 yards the guns were first fired by men not specially instructed, and afterwards by the same men after a thorough course of instruction, and it was found that the mean deviation was reduced in the proportion of 3 to 2. Under the ordinary conditions of naval gunnery the advantage gained would be in a much greater proportion, since it is more difficult to lay a gun mounted on a moving platform than when it is fixed.

The same book also states—

Errors.

(*a.*) The mean vertical error of laying with men of good eyesight has been found to be about one minute, this is about equivalent with a good field gun to a difference of about 10″ at 1,100 yards.

(*b.*) Taking a fine or half instead of a full sight will cause still greater errors. For instance, the former in an average gun will make a difference of about 5 minutes equal to 4½ feet vertical height at 1,100 yards.

(*c.*) Similar errors will occur in deflection if the point of the foresight is not kept in the centre of the notch.

Care must be taken in adjusting the sights, and much depends on the eyesight of the firer and on the visibility of the target.

This latter again varies with the nature of target and background, and the state of the atmosphere and weather.

Injuries to the sights will cause errors, but if permanent these may be allowed for.

Inclination of trunnions.

(6.) Owing to the gun being sighted when the trunnions are horizontal, there arises an error in fire when they are inclined. If the gun is laid by the sights, the projectile deflects towards the side of the lower trunnion, and accordingly allowance must be made on the deflection scale by moving it towards the upper trunnion.

The amount of this error can be obtained from formula, page 211.

This point must be attended to with field guns.

With ship guns mounted on the broadside, even when they are extreme trained, this error may be neglected, but when firing ahead or astern, if the ship should be heeling, it must be allowed for.

Unsteadiness of gun and carriage.

(7.) Unsteadiness of the gun and carriage may result from too large a charge being used for the weight of the gun and carriage, causing an excessive jump. The nature of the mounting, the apparatus used to check recoil, and the angle of elevation probably affect the jump, but no reliable information relative to this is obtainable.

All these errors, however, are, as regards naval gunnery, subordinate to those arising from the movement of the platform, the object, or both.

This subject will be treated in the next chapter.

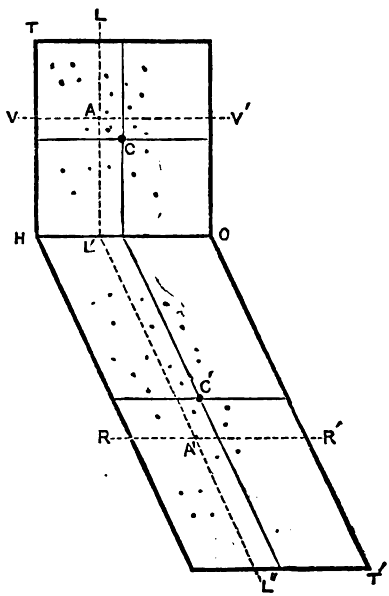
## Method of Measuring Accuracy.

In order to judge of the absolute accuracy of fire of a gun it is necessary to fire a large number of rounds at a target, and to do this under conditions as favourable as possible to the gun. Method of procedure.

Under these circumstances, errors of fire No. 4, No. 5, and No. 6 should be practically eliminated, and the remainder, by care and attention, should be reduced to a minimum, which will vary in extent according to the qualities of the gun and ammunition.

The accuracy may be estimated either on a horizontal target, or on a vertical in addition. Measuring accuracy.

This latter method of calculating the accuracy is the most convenient for naval purposes.




Suppose TO to be a vertical target, the gun firing from the other side, and HT′ a horizontal target taken so that all shot passing through the vertical target will fall on it.

C is the centre of the target on which the gun is laid, and the line of sight is supposed to pass through this point.

Similarly, C″ is the point on the horizontal target on which a shot passing through C should fall.

Mean range. The *mean range* is obtained by dividing the sum of the ranges of each shot by the number of rounds fired. Thus, RR′ represents the line of mean range.

Mean deviations:— Lateral. The *lateral deviation** of each shot is its distance from the centre line, and may be estimated on either the horizontal or vertical target, and the *mean lateral deviation* is obtained by dividing the algebraical sum of these lateral deviations by the number of rounds fired. Thus, LL′ or L′L″ represents the line of mean lateral deviation.

Vertical. The *vertical deviation** of each shot is its distance from the horizontal line passing through the centre of the target, and the *mean vertical deviation* is obtained by dividing the algebraical sum of these vertical deviations by the number of rounds fired. Thus, VV′ represents the line of mean vertical deviation.

Points of mean impact. The intersection of the lines RR′ and L′L″ gives A′, the *point of mean impact* on the horizontal target; and the intersection of the lines LL′ and VV′ gives A, the *point of mean impact* on the vertical target.

Mean errors:— In range. The difference between the range of each shot and the mean range is the *error in range*, and the *mean error in range*, or the mean longitudinal error, is obtained by taking the numerical sum of these differences and dividing by the number of rounds fired.

Lateral. The difference between the lateral deviation of each shot and the mean lateral deviation is the *lateral error*, and the *mean lateral error* is obtained by taking the numerical sum of these differences and dividing by the number of rounds fired.

Vertical. The difference between the vertical deviation of each shot and the mean vertical deviation is the *vertical error*, and the *mean vertical error* is obtained by taking the numerical sum of these differences and dividing by the number of rounds fired.

Absolute. The *absolute error* of each shot is the radial distance from the point of mean impact, and may be estimated either on the horizontal or vertical target.

* Note.—The lateral and vertical deviations are often for convenience measured from the side and foot of the target. In this case the mean is obtained by taking the arithmetical sum of deviations and dividing as before by number of rounds.

The *mean absolute error* is obtained by taking the sum of these absolute errors and dividing by the number of rounds fired.

In order to estimate the relative accuracy of small-arms, the *mean absolute error* is taken on a vertical target. To estimate the relative accuracy of ordnance the *mean longitudinal, lateral,* and *vertical errors* are observed.

As an example of testing guns for range and accuracy the following examples are given, taken from the practice with Krupp guns at Meppen, August 1879. **Example of calculation.**

They show also the very great accuracy which can be obtained from the largest guns.

Gun 40 c.m. ($15\frac{3}{4}$ inch); weight, 70·86 tons, including wedge; length of bore in calibres, 21·1; charge, 452 lbs. prismatic; projectile, 1,712 lbs., 2·8 calibres long; M.V. 1648 f.s.

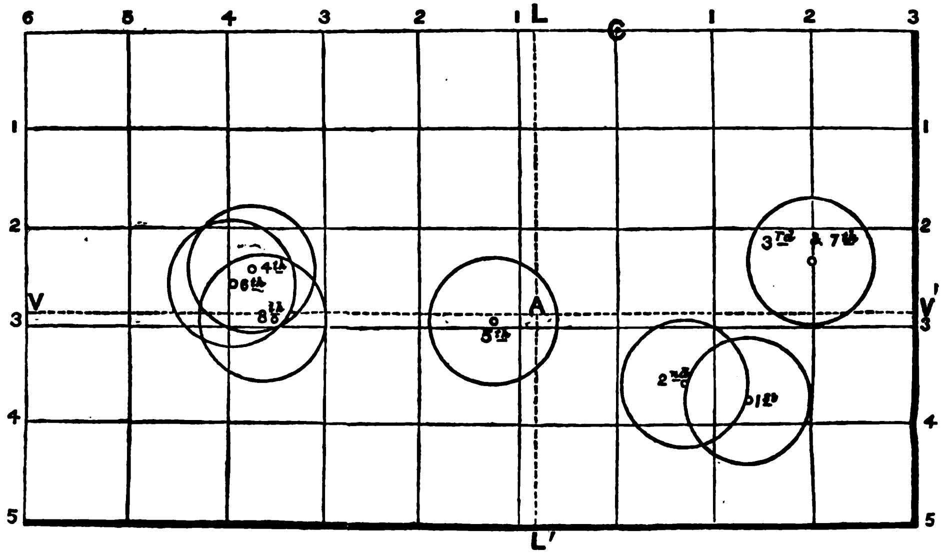
Eight Rounds fired at Vertical Target 16′ square.

| No. of Round. | Range. | Difference of each Range from Means. | From Centre of Vertical Target, | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Vertical. | | | Lateral. | | |
| | | | Deviation. | | Error. | Deviation. | | Error. |
| | | | Above. | Below. | | Left. | Right. | |
| | Yds. | Yds. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. |
| 1 | 2,810 | 4 | — | 45·2 | 10·8 | — | 15·75 | 25·59 |
| 2 | 2,816 | 2 | — | 43·3 | 8·9 | — | 7·9 | 17·74 |
| 3 | 2,815 | 1 | — | 27·5 | 6·9 | — | 23·6 | 33·44 |
| 4 | 2,812 | 2 | — | 29·5 | 4·9 | 43·3 | — | 33·46 |
| 5 | 2,808 | 6 | — | 35·4 | 1·0 | 15·75 | — | 5·91 |
| 6 | 2,815 | 1 | — | 31·5 | 2·9 | 47·24 | — | 37·40 |
| 7 | 2,817 | 3 | — | 27·5 | 6·9 | — | 23·6 | 33·44 |
| 8 | 2,818 | 4 | — | 35·4 | 1·0 | 43·3 | — | 33·46 |
| 8 | 22,511 | 23 | — | 275·3 | 43·3 | 149·59<br>70·85<br>78·74 | 70·85 | 220·44 |
| | Mean 2,814 | Mean 2·87 | Mean vertical deviation | 34·4 | Mean 5·4 | 9·84 Left | Mean lateral deviation | Mean 27·55 |

| | | |
|---|---|---|
| Mean range | - - - - | 2,814 yards. |
| " error in range | - - - | 2.87 " |
| " " vertically | - - - | 5·4 inches. |
| " " in direction (lateral) | - - | 27·55 " |
| Greatest difference in range | - - | 10 yards. |
| Greatest difference vertically | - - | 17·7 inches. |
| Greatest difference in direction | - - | 70·84 " |

The rectangle on the vertical target which contained the centres of all the eight shot measured 1·4 feet in height and 5·9 feet in breadth.

**Diagram** showing the position of the 8 shot which struck the target. The diagram represents a portion of the vertical target fired at divided into one-foot squares.




C, is the centre of target and point aimed at.
LL', line of mean lateral deviation.
VV', „ vertical „
A, point of mean impact.

## Probability of Hitting.

Probability of hitting.

Having found these mean errors, the probability of hitting any object of a given size may be found by the theory of probabilities, by the aid of which is calculated the table of factors of probability annexed, and also the factor ·8453, by which the mean error must be multiplied to get the probable error.

Probable error.

By *probable error* is meant that half the shots may be expected to have an error greater than the probable error, and the other half less.

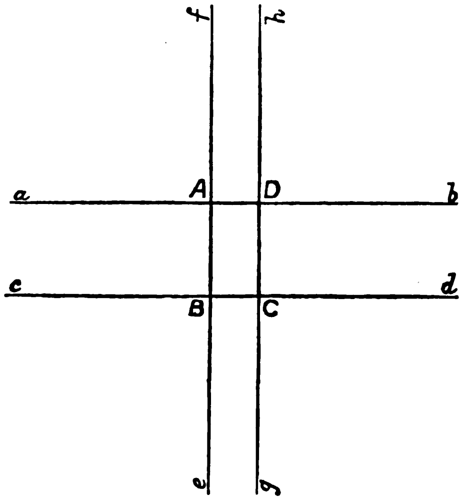
By taking twice this factor (*i.e.* on either side of the mean line) we get 1·69 as the factor by which the mean error in

any direction must be multiplied to get the zone of fire within which 50 per cent. of the shot would probably strike. Zones of fire.

If the mean error in range be denoted by $R$,
" " lateral error " $L$.
" " vertical error " $V$,

the depth of the zone containing 50 per cent. of the shot is - - - - $1 \cdot 69R$,
the breadth " " " " $1 \cdot 69L$,
the height " " " " $1 \cdot 69V$.

These zones of fire are quite independent of one another, and are bounded by two indefinite parallel straight lines, distant from one another by the amount given above. In practice, however, it is sufficient for the other dimension to be eight *times* the probable error, as it will then contain more than 99 per cent. of the total number in that zone. (*See* Table p. 178.)




Thus, firing at a horizontal target, if $R$ is the mean error in range, then the length included between the two indefinite parallel straight lines *ab* and *cd*, distant $1 \cdot 69R$ from one another, represents the depth of the zone containing 50 per cent. of the shot fired; and if $L$ is the mean lateral error, then the length included between the two indefinite parallel straight lines *ef* and *gh*, distant $1 \cdot 69L$ from one another, represents the breadth of the zone containing 50 per cent. of the shot fired. 50°/o zone.

Probable rectangles. 25 %.

The rectangle, *ABCD*, enclosed by the intersection of these zones represents the area in which 50 per cent. of 50 per cent. —*i.e.*, 25 per cent.—of the shot will probably strike. A vertical rectangle may also be obtained in the same way, if the mean vertical and lateral errors are known. These are called *probable rectangles*, and the above is the method of calculating them usually adopted on the Continent.

A comparison of rectangles made out from the results obtained by firing different guns affords a good criterion of their respective accuracy of fire.

The dimensions of the British probable rectangle hitherto adopted are 1·56 times larger than those of the former, but it is proposed in future to adopt the probable rectangle in use on the Continent.

50 %.

The British probable rectangle represents the area in which 50 per cent. of the shot will probably strike—*i.e.*, twice the probable number of shots contained in the Continental rectangle.

The sides of the British 50 per cent. probable rectangle may be directly obtained by multiplying the mean errors by $1·69 \times 1·56 = 2·64$.

Probability factors.

When the mean errors of a gun at a given range are known, the probability of hitting a target of given dimensions can be calculated by means of a Table of Probability Factors.

The following table gives factors by which the dimensions of the zones containing 50 per cent. of the shot must be multiplied in order to determine the per-centage of hits on a target of given dimensions:—

Table.

TABLE of Probability Factors.

| Per Cent. | Factor. | Per Cent. | Factor. | Per Cent. | Factor. | Per Cent. | Factor. | Per Cent. | Factor. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ·02 | 21 | ·40 | 41 | ·80 | 61 | 1·27 | 81 | 1·94 |
| 2 | ·04 | 22 | ·41 | 42 | ·82 | 62 | 1·30 | 82 | 1·98 |
| 3 | ·06 | 23 | ·43 | 43 | ·84 | 63 | 1·33 | 83 | 2·03 |
| 4 | ·07 | 24 | ·45 | 44 | ·86 | 64 | 1·36 | 84 | 2·08 |
| 5 | ·09 | 25 | ·47 | 45 | ·89 | 65 | 1·39 | 85 | 2·13 |
| 6 | ·11 | 26 | ·49 | 46 | ·91 | 66 | 1·42 | 86 | 2·18 |
| 7 | ·13 | 27 | ·51 | 47 | ·93 | 67 | 1·45 | 87 | 2·24 |
| 8 | ·15 | 28 | ·53 | 48 | ·95 | 68 | 1·48 | 88 | 2·30 |
| 9 | ·17 | 29 | ·55 | 49 | ·98 | 69 | 1·51 | 89 | 2·37 |
| 10 | ·18 | 30 | ·57 | 50 | 1·00 | 70 | 1·54 | 90 | 2·44 |

TABLE of Probability Factors—*cont.*

| Per Cent. | Factor. | Per Cent. | Factor. | Per Cent. | Factor. | Per Cent. | Factor. | Per Cent. | Factor. |
|---|---|---|---|---|---|---|---|---|---|
| 11 | ·20 | 31 | ·59 | 51 | 1·02 | 71 | 1·57 | 91 | 2·52 |
| 12 | ·22 | 32 | ·61 | 52 | 1·04 | 72 | 1·60 | 92 | 2·60 |
| 13 | ·24 | 33 | ·63 | 53 | 1·07 | 73 | 1·64 | 93 | 2·69 |
| 14 | ·26 | 34 | ·65 | 54 | 1·09 | 74 | 1·67 | 94 | 2·78 |
| 15 | ·28 | 35 | ·67 | 55 | 1·12 | 75 | 1·71 | 95 | 2·91 |
| 16 | ·30 | 36 | ·70 | 56 | 1·14 | 76 | 1·74 | 96 | 3·0 |
| 17 | ·32 | 37 | ·72 | 57 | 1·17 | 77 | 1·78 | 97 | 3·22 |
| 18 | ·34 | 38 | ·74 | 58 | 1·19 | 78 | 1·82 | 98 | 3·45 |
| 19 | ·36 | 39 | ·76 | 59 | 1·22 | 79 | 1·86 | 99 | 3·82 |
| 20 | ·38 | 40 | ·78 | 60 | 1·25 | 80 | 1·90 | 100 | $\infty$ |

*Example.*—What per-centage of shot fired from a gun at a mean range of 2000 yards will probably hit a vertical target 5 feet high by 30 feet broad, if the mean vertical error is 1·5 feet and the mean lateral error 5·5 feet? **Example.**

The height of the zone containing 50 per cent. of the shot is $1·5 \times 1·69 = 2·53$ feet; the breadth of the zone containing 50 per cent. of the shot is $5·5 \times 1·69 = 9·29$ feet.

*The probability factor for height* is obtained by dividing the height of the target by the height of the zone containing 50 per cent. of the shot. Thus:— **Factor for height.**

$$\text{Probability factor for height} = \frac{5}{2·53} = 1·97.$$

By reference to the Table of Probability Factors it will be seen that 1·97 corresponds to 81·7 per cent., which shows that 81·7 per cent. of the shot will probably fall into a zone 5 feet in height, and of indefinite length.

*The probability factor for breadth* is obtained by dividing the breadth of the target by the breadth of the zone containing 50 per cent. of the shot. Thus:— **For breadth.**

$$\text{Probability factor for breadth} = \frac{30}{9·29} = 3·22.$$

By reference to the Table of Probability Factors it will be seen that 3·22 corresponds to 97 per cent., which shows that 97 per cent. of the shot will probably fall into a zone 30 feet in breadth and of indefinite length.

The product of the per-centages thus found will give the per-centage of hits on the target. Thus, probable number of hits = 81·7 per cent. of 97 per cent. = 79·2 per cent.

The same method applies for determining the per-centage of hits on a horizontal target, if the mean vertical and lateral errors of the gun are known.

Tables of accuracy for guns.

For the German artillery accuracy tables are calculated and tabulated for all guns.

They are based upon practice, and may be assumed to be correct, provided that gun, ammunition, and service are in good order, that errors in elevation or deflection are not made, and that the weather does not exercise any particular disturbing influence.

These tables contain data as to the size of the zones within which half the shots may be expected to fall at various ranges.

They are very useful, and it is much to be desired that similar tables should be calculated and issued for our S.S. ordnance. This has not yet been done, but the following table gives the results for the 13-pr. R.M.L. gun. M.V. 1595 f.s.

| Range. | Angle of Descent. | | 50 per Cent. of Rounds fired should fall within | | |
|---|---|---|---|---|---|
| | | | Length. | Breadth. | Height. |
| Yds. | ° | ′ | Yds. | Yds. | Yds. |
| 500 | 0 | 51 | 4·70 | 0·30 | 0·06 |
| 1,000 | 1 | 59 | 12·15 | 0·77 | 0·36 |
| 1,500 | 3 | 21 | 18·00 | 1·14 | 1·02 |
| 2,000 | 5 | 1 | 23·25 | 1·44 | 2·05 |

See also Appendix, p. 504.

# NAVAL GUNNERY.

## CHAPTER VIII.

## ACCURACY AT SEA.

### Firing at Sea.

*Special Errors.*

In addition to the errors mentioned in the last chapter, which apply to guns mounted in all positions whether afloat or ashore, there are two special ones which detract from the accuracy of naval guns to a much greater extent. **Errors due to motion.**

These are—

1. The rolling and pitching of the ship;
2. Changes in the distance and bearing of the enemy.

As regards the first, there are no records of any experiments ever having been carried out with rifled guns to ascertain to what extent the motion of the ship affects the accuracy. Much depends upon whether the vessel is a quick or slow roller, and of late years great efforts have been made to give increased steadiness of gun platform, so as to reduce this cause of error somewhat. **Rolling and pitching.**

This is shown in the following table, which gives the natural period, or time of rolling from starboard to port (or *vice versâ*), of ships in still water:— **Still water periods.**

| Ship. | Time. |
|---|---|
| Newcastle - - - | 5·00 seconds. |
| Defence - - - | 5 to 5·5 „ |
| Devastation - - - | 6·76 „ |
| Minotaur - - - | 7 to 7·5 „ |
| Inconstant - - - | 8·0 „ |
| Sultan - - - | 8·90 „ |

Changes in the distance and bearing of the object fired at exert very considerable influence on the possibilities of hitting. In default of experimental data, an attempt will now be made to explain this.

Causes of error.

The errors arising from firing at an object in motion, in addition to those which exist when it is stationary, are due generally to one of the following causes:—

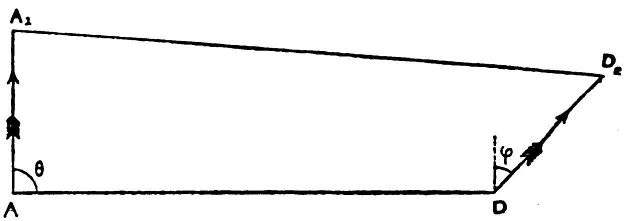
1. Alterations in the distance.
2. " in the bearing.
3. The size of the *virtual* target.

### *Changes in Distance.*

Changes in distance.

To find the alteration in the distance in a given small interval of time between two ships moving uniformly in given directions.

Fig. 1.



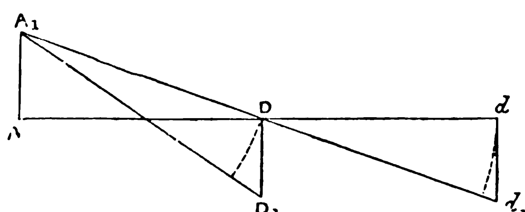

Let A and D be the two ships moving uniformly in the directions of the arrows, and let $A_1$ and $D_2$ be their positions at the end of a given time.

Then the distance between them will be $A_1D_2$ instead of AD, and the difference between these two quantities will be the alteration in the distance required.

Change of distance varies with initial distance.

The changes in the distance vary slightly with the initial distance. This is due to the change in the obliquity of the line $A_1D_1$ with reference to AD.

Fig. 2.



This can be seen from Fig. 2, in which $AA_1$, $DD_1$, and $dd_1$ represent the distances traversed by the vessels in the interval of time. If the initial distance $AD = 500$ yards, the alteration in the distance will be $A_1D_1 - AD$; whereas if the initial distance is $Ad$, the change will be $A_1d^1 - Ad$. It is evident from the figure that these quantities are not necessarily the same. Changes in distance.

The difference between the values of $A_1D_2$ and AD have been calculated with the following data:—

$AD = 500$ yards, and $= 1{,}000$ yards.

$AA_1 = DD_2 = 169$ yards, which is the distance passed over in 30 seconds, when the speed is 10 knots an hour.

It will be observed that the results obtained will vary with—

1. The angle ($\theta$) between the direction of motion of A and the bearing of D.
2. The angle ($\varphi$) between the directions of motion of A and D.

The values of $\theta$ taken have therefore been 0, 45°, 90°, &c., and to each of these a series of values of $\varphi = 0, 45, 90$, &c. The results are shown in the following table:—

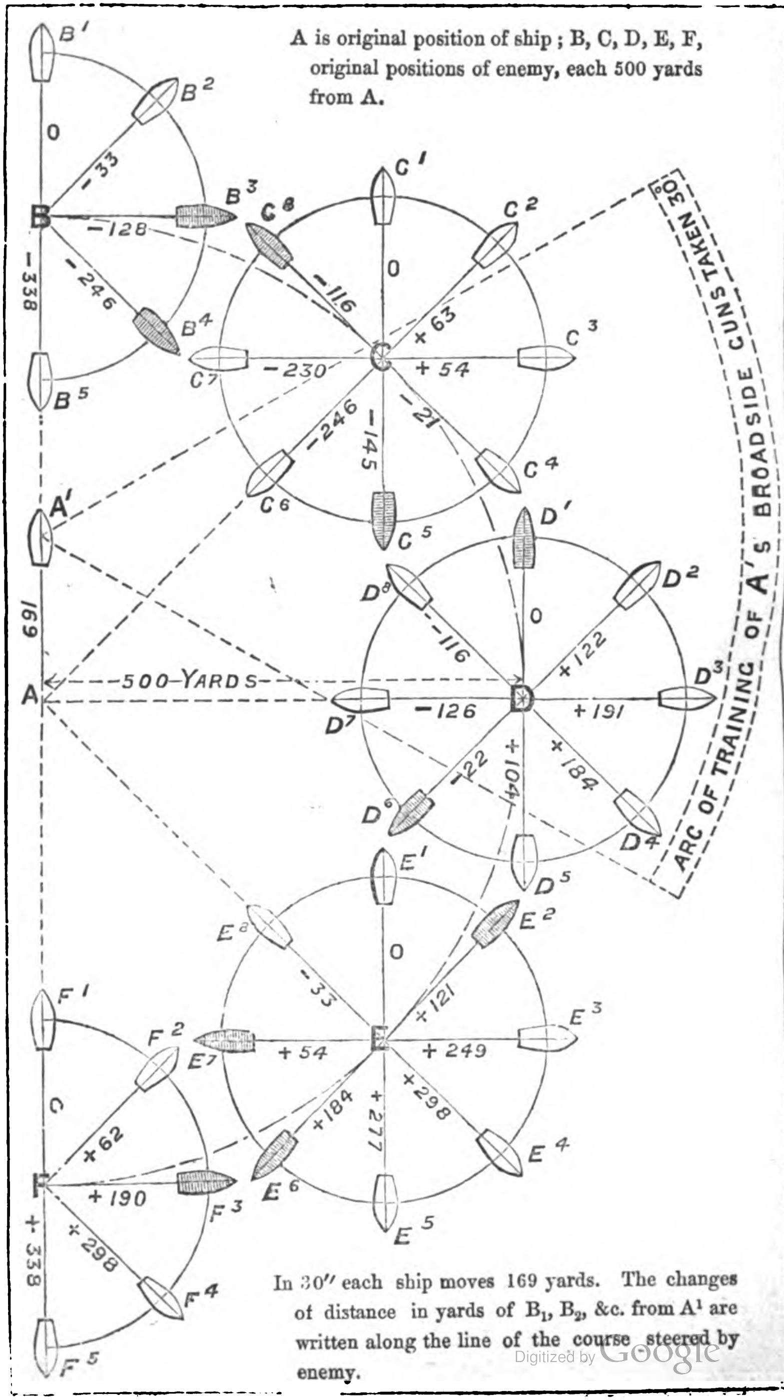
Showing the change in the distance in yards in 30 seconds between two objects moving at a speed of 10 knots.

| Initial Distance. | Angle between the Direction of Motion of A and the Bearing of D. | Angles between the Directions of Motion $\phi$. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0. | 45°. | 90°. | 135°. | 180°. | 225°. | 270°. | 315°. |
| Yards. | ($\theta$.) | | | | | | | | |
| 500 | 0 | 0 | −33 | −128 | −246 | −338 | −246 | −128 | − 33 |
| | 45 | 0 | +63 | + 54 | − 21 | −145 | −246 | −238 | −116 |
| | 90 | 0 | +122 | +191 | +184 | +104 | − 22 | −126 | −116 |
| | 135 | 0 | +121 | +249 | +298 | +277 | +184 | + 54 | − 33 |
| | 180 | 0 | + 62 | +190 | +298 | +338 | +298 | +190 | + 62 |
| 1,000 | 0 | 0 | − 42 | −152 | −280 | −338 | −280 | −152 | − 42 |
| | 45 | 0 | + 58 | + 32 | − 72 | −202 | −278 | −240 | −118 |
| | 90 | 0 | +122 | +180 | +160 | + 56 | − 74 | −154 | −118 |
| | 135 | 0 | +121 | +240 | +295 | +264 | +156 | + 28 | − 42 |
| | 180 | 0 | + 57 | +182 | +296 | +338 | +296 | +182 | + 57 |

To enable this table to be more readily understood, the diagram, p. 184, has been drawn to scale, and is introduced to show the changes in the distance when the initial range is 500 yards. Diagram.

Allowing 30° training on each side of the beam, the shaded ships show the positions where the broadside guns of the enemy will bear.

A is original position of ship; B, C, D, E, F, original positions of enemy, each 500 yards from A.




In 30″ each ship moves 169 yards. The changes of distance in yards of $B_1$, $B_2$, &c. from $A^1$ are written along the line of the course steered by enemy.

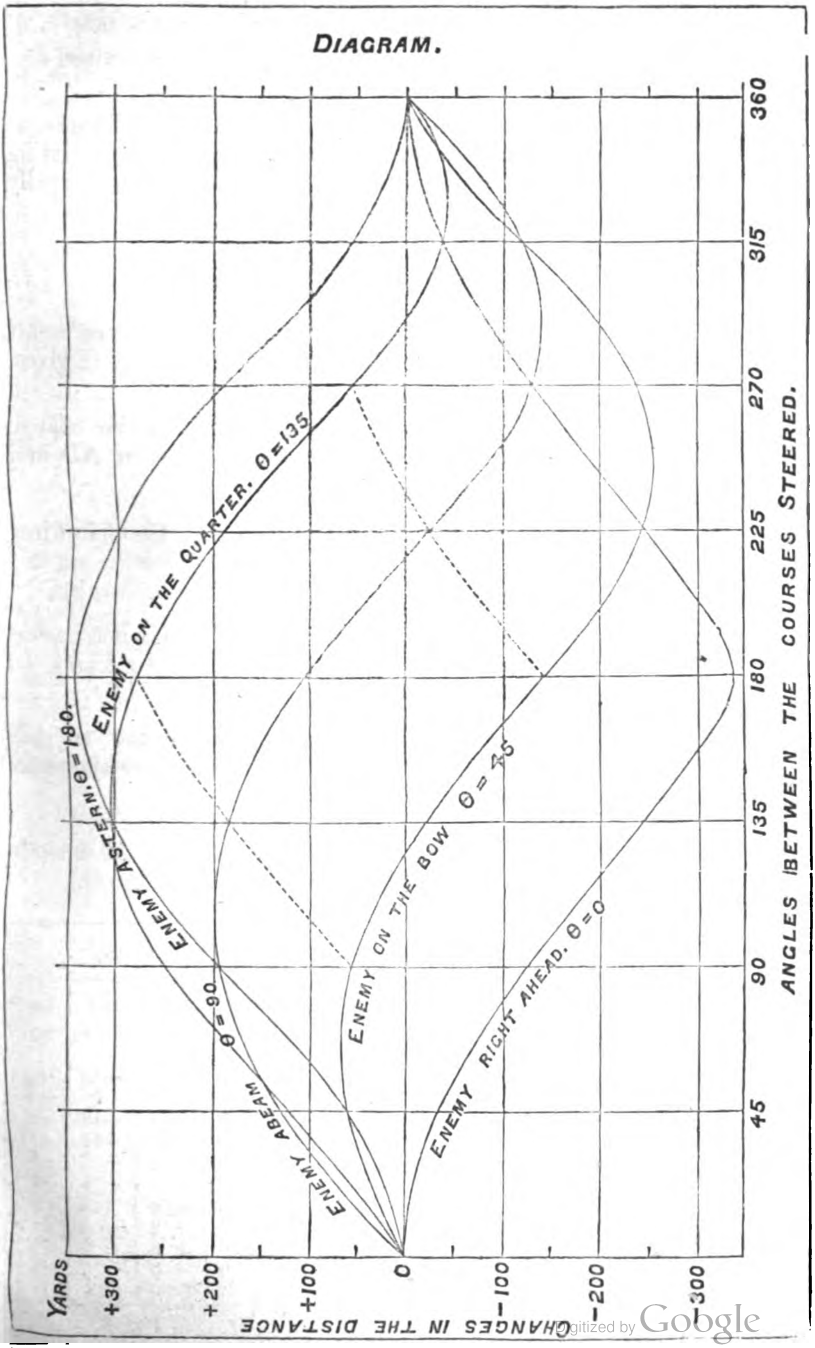


DIAGRAM.
YARDS
+300
+200
+100
0
−100
−200
−300
CHANGES IN THE DISTANCE
45
90
135
180
225
270
315
360
ANGLES BETWEEN THE COURSES STEERED.
ENEMY ASTERN. θ=180.
ENEMY ON THE QUARTER. θ=135
ENEMY ABEAM
θ=90
ENEMY ON THE BOW θ=45
ENEMY RIGHT AHEAD. θ=0

For those who are accustomed to viewing such questions in the form of curves, the diagram, p. 185, will be instructive.

The portion of the table corresponding to the initial distance of 500 yards is here graphically represented.

A comparison of these diagrams with the curves of dangerous space on p. 131 will show the small probability of hitting at any but short ranges when the distance is rapidly changing.

### *Changes in Bearing.*

Changes in bearing.

To find the alteration in the bearing in a given small interval of time between two ships moving uniformly in given directions.

Referring to Fig. 1, it will be observed that the change in the bearing of D from A is the angle between AD and $A_1D_2$.

These angles have been ascertained for the following data:—

AD = 300 and 600 yards.

$AA_1 = DD_2 = 56{\cdot}3$ yards, which is the distance passed over in 10 seconds when the speed is 10 knots an hour.

The results have been tabulated on a plan similar to that used for the change of distance, and the results are shown in the following table.

Change of bearing.

SHOWING the change in the bearing in degrees in 10 seconds between two ships moving at a speed of 10 knots.

| Initial Distance. | Angle between the Course and the Bearing of the Enemy. | Angles between the Courses Steered. ($\phi$). 0. | 45°. | 90°. | 135°. | 180°. | 225°. | 270°. | 315°. |
|---|---|---|---|---|---|---|---|---|---|
| Yards. | $\theta$. | | | | | | | | |
| 300 | 0 | 0 | +8 | +13 | +11 | 0 | −11 | −13 | −8 |
| | 45 | 0 | +7 | +14 | +20 | +19 | +11 | 0 | −3 |
| | 90 | 0 | +2 | +8 | +15 | +20 | +20 | +12 | +3 |
| | 135 | 0 | −3 | 0 | +5 | +11 | +15 | +14 | +7 |
| | 180 | 0 | +5 | +8 | +7 | 0 | −7 | −8 | −5 |
| 600 | 0 | 0 | +3 | +5 | +4 | 0 | −4 | −5 | −3 |
| | 45 | 0 | +3 | +7 | +9 | +8 | +4 | 0 | −2 |
| | 90 | 0 | +1 | +5 | +8 | +10 | +9 | +5 | +1 |
| | 135 | 0 | −1 | 0 | +2 | +6 | +8 | +7 | +3 |
| | 180 | 0 | +3 | +5 | +3 | 0 | −3 | −5 | −3 |

**Time** required to pass across the field of fire of a gun training 30° each way. Time to pass across field of fire.

| Speed of Object relative to Ship. | Distance in Yards when Enemy is Abeam. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100. | | 200. | | 400. | | 600. | | 800. | | 1,000. | |
| | m. | s. | m. | s. | m. | s. | m. | s. | m. | s. | m. | s. |
| 6 knots - - | 0 | 34 | 1 | 8 | 2 | 16 | 3 | 24 | 4 | 32 | 5 | 40 |
| 8 " - - | 0 | 26 | 0 | 52 | 1 | 44 | 2 | 36 | 3 | 28 | 4 | 20 |
| 10 " - - | 0 | 21 | 0 | 42 | 1 | 24 | 2 | 6 | 2 | 48 | 3 | 30 |
| 12 " - - | 0 | 17 | 0 | 33 | 1 | 6 | 1 | 39 | 2 | 12 | 2 | 45 |
| 14 " - - | 0 | 15 | 0 | 29 | 0 | 58 | 1 | 27 | 1 | 56 | 2 | 28 |
| 16 " - - | 0 | 13 | 0 | 26 | 0 | 52 | 1 | 18 | 1 | 44 | 2 | 10 |
| 20 " - - | 0 | 10 | 0 | 21 | 0 | 42 | 1 | 3 | 1 | 24 | 1 | 45 |
| 24 " - - | 0 | 8 | 0 | 16 | 0 | 32 | 0 | 49 | 1 | 6 | 1 | 22 |

In the calculation of this table the ship and object have been assumed to move in parallel directions.

*Size of virtual Target.*

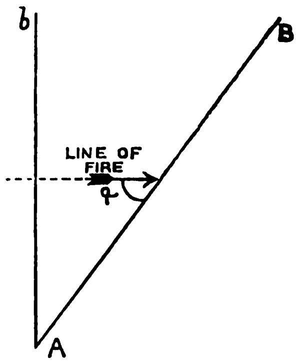
The size of the *virtual* target depends upon the position of the enemy's ship with reference to the line of fire.

By *virtual* target is meant the vertical target equivalent to the object fired at. Definition.

If the object is a simple vertical plane at right angles to the line of fire, the virtual and real targets are identical.

But if the object is a vertical plane inclined at an angle ($\alpha$) to the line of fire, the width and form of the virtual target are modified.

Fig. 3.

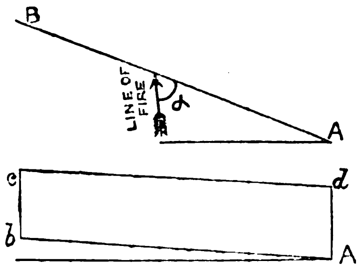



Thus, if AB is the object, the width of the virtual target is given by

$$Ab = AB \times \sin \alpha.$$

Again in Fig. (4), if $Ad$ is the actual height, and the

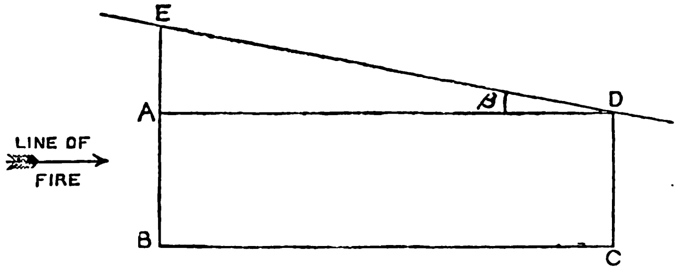
Fig. 4.




object is inclined at an angle $\alpha$, the form of the virtual target will be that of A *b c d*, since the portion of the target towards B will be raised by the angle of descent.

If the object has depth as well as height, the *virtual* target is found as follows. To the real height add the depth of the object × tangent of the angle of descent.

Fig. 5.




Thus, if ABCD be a vertical section of the object taken in the direction of the line of fire in which AB is the height, and AD the depth. Then, if EDA be the angle of descent for the given range, BE is the *virtual* target, while AB is the real vertical target, and AE = AD tan $\beta$.

Table to find virtual target.

The additions, in feet, which must be made to the real targets to obtain the virtual, are given in the following table :—

| Angles of Descent. | Depth of Object in Feet. | | | | | |
|---|---|---|---|---|---|---|
| | 50. | 100. | 150. | 200. | 250. | 300. |
| ° | | | | | | |
| ½ - - - | ·4 | ·9 | 1·3 | 1·8 | 2·2 | 2·6 |
| 1 - - - | ·9 | 1·7 | 2·6 | 3·5 | 4·4 | 5·2 |
| 1½ - - - | 1·3 | 2·6 | 3·9 | 5·2 | 6·5 | 7·8 |
| 2 - - - | 1·7 | 3·5 | 5·2 | 7·0 | 8·7 | 10·4 |
| 2½ - - - | 2·2 | 4·4 | 6·5 | 8·8 | 10·0 | 13·1 |
| 3 - - - | 2·6 | 5·2 | 7·9 | 10·5 | 13·1 | 15·8 |
| 3½ - - - | 3·1 | 6·1 | 9·1 | 12·2 | 15·2 | 18·3 |

In the case of a ship the height of the virtual target is a minimum when she is broadside on, and increases to a maximum when she is end on.

If the object is inclined to the line of fire, the width of the virtual target is the projection of the width of the object on the plane perpendicular to this line.

When it is desired to ascertain the probability of hitting a ship, the size of the virtual target for the particular distance and direction of ship's head must be determined.

The forms of these targets are shown in the annexed diagrams, which represent them for a ship 300 × 50 feet, and for an angle of descent of 5°. **Examples.**

In each figure ABC represents the ship in plan. In Fig. 6 when she is broadside on, HKLM is the vertical section, and H*k*LM the virtual target.

In Fig. 7, when the ship is at an angle of 45° to the line of fire, the virtual target is represented by KLMNOP.

In Fig. 8, WXYZ is the énd on vertical section, and *wx*YZ the virtual target in this case.

Fig. 6.

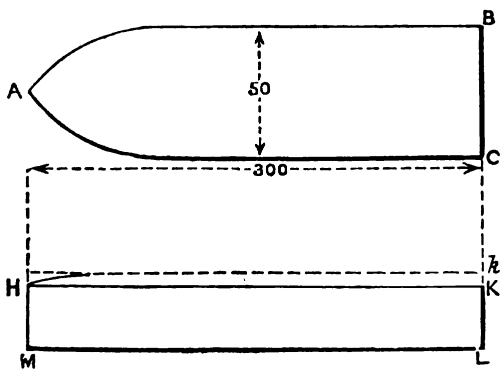


Fig. 7.

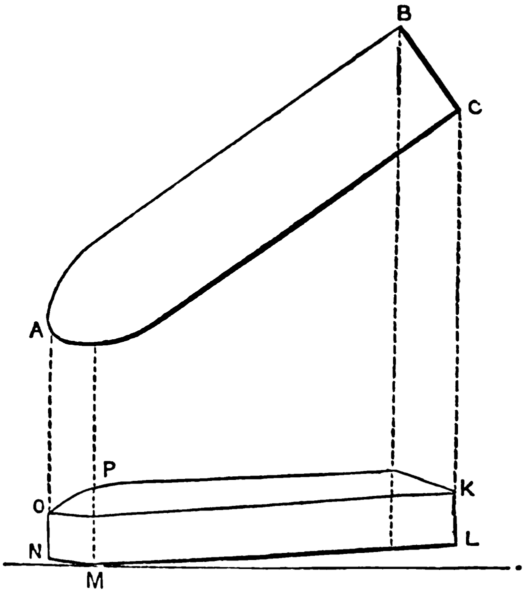
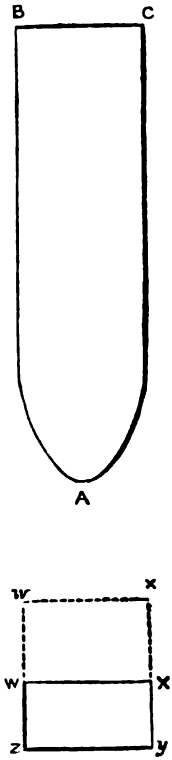



Fig. 8.



# CHAPTER IX.

## CONCENTRATING.

### General Remarks.

By concentrating is understood laying a number of guns on some fixed bearing or bearings in such a manner that at certain given distances all the projectiles converge on one point. **Definition.**

Under the head of "Systems of Firing" will be found fully discussed the question as to the value of concentrating, and the occasions on which the system would be adopted in preference to other methods of firing, and therefore it is sufficient here to assume that in all ships carrying more than a certain number of guns some system of concentrating the fire is a necessity. **Necessity for use is assumed.**

This has been recognised in our service for many years, and has more recently been adopted in most foreign navies.

The system of laying the guns which has been in use in our navy is of rather a complicated nature, and may be described as follows:— **System hitherto in use.**

The rear racers are graduated in degrees before and abaft the beam, and a pointer is fixed to the slide, &c., the beam mark being placed so that the gun when trained to bring the pointer on this bearing shall have its axis at right angles to the keel.

This method of laying the guns may be used at any distance and on any bearing which the amount of training will admit of; but, as may be seen from the manner in which the beam mark is fixed, the guns when laid on any named bearing are always parallel.

In order to converge the fire at any given distance the angles are calculated according to the distance before or abaft the centre gun, and a correction table is fixed to each slide.

When the guns are ordered to converge at any named bearing and distance, each No. 1 (except No. 1 of centre gun) takes from the table the correction due to the distance for his particular gun, adds it to or subtracts it from the named bearing, and then lays his gun for the amended bearing.

The correction of the director is calculated from the centre gun, and applied in similar manner.

Objections.

This plan is open to many objections on the score of complication, and may be considered as inapplicable to service conditions. Mistakes are frequently made even at drill, and the performance of addition and subtraction when actually engaged is plainly inadvisable.

Alternative method.

This was to a certain extent recognised at the time of its introduction, and accordingly matters were still further complicated by the introduction of a special plan for use at short ranges and on five fixed bearings, leaving the more general method to be used at long ranges and on any other bearings which might be required.

This special plan was that of calculating the corrections from the centre gun, for distances of 200, 300, 400, and 600 yards, on bearings of abeam, and one and two points before and abaft the beam, and then fixing on those bearings converging plates with a separate mark for each distance.

Advantages.

This plan, as will easily be seen, has great advantages in comparison with the use of a correction table, and practically the only liability to error consists in the Nos. 1 mistaking the distance marks on the converging plate, which would however make no practical difference at such short ranges.

The increased simplicity has led to the universal adoption of the latter plan in our navy, but concentrating by correction table is still retained as an alternative.

System to be used in future.

Taking into consideration the immense advantage of increased simplicity it would seem that the best plan for converging is—

1. To have only one fixed distance.
2. This distance, for reasons stated below, to be 600 yards.
3. To have five bearings, viz., abeam, bow, quarter, and 15° before and abaft the beam, and to have the director marked for these points.
4. To have marks fixed for these bearings, and some mechanical means, such as a stop handspike or catch by which the gun can be accurately laid, with no probability of error.
5. The marking of the racers in degrees to be retained for the purpose of pointing out the direction of the object in other firings, but not to be used for concentrating.

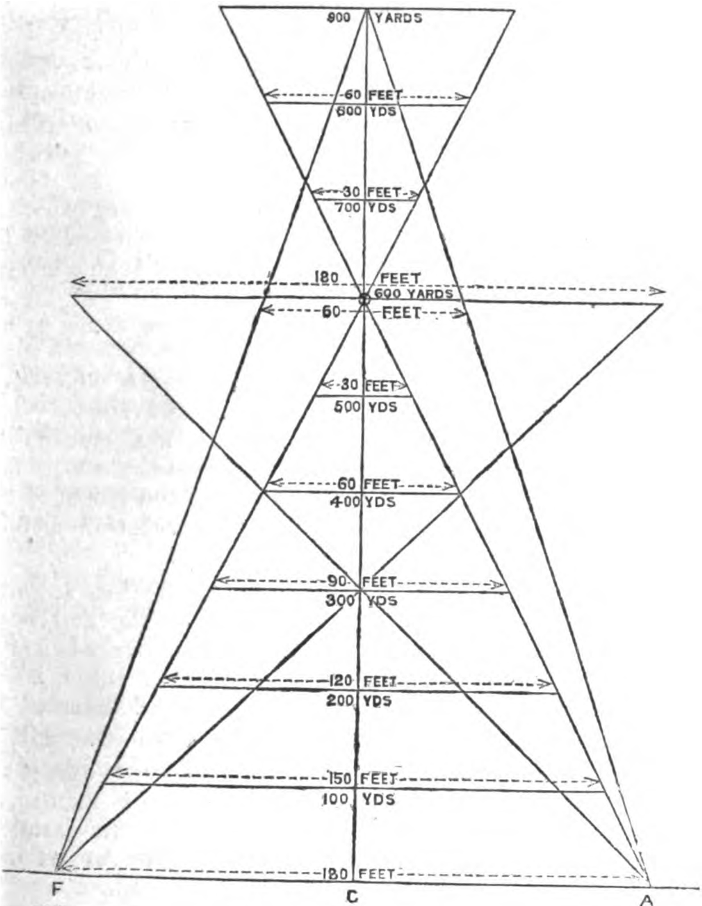
Reasons for fixed distances as regards horizontal plane.

(1) and (2.) The reasons for the selection of one fixed distance on which to concentrate *horizontally* the fire of the guns will be seen from the following sketch which represents the lateral space covered by the shot in what may be considered an extreme case where the length of the battery is taken as

180 feet; it must, however, be noted that for clearness the ranges and lateral spaces are not drawn on the same scale.

Reasons for fixed distance.

Fig. 1.




F Foremost gun. C Centre gun. A After gun.

If the guns are laid, and corrections calculated for any given distance, it is evident that at other ranges there will be a certain lateral error.

If the broadside is concentrated for a distance of 300 yards the sketch shows that up to 400 yards the shot will strike closer together than if the concentration were for 600 yards, and beyond that distance the shot diverge rapidly, and the fire consequently soon becomes ineffective. At ranges below

100 yards the difference is not great, and looking to the impossibility of foreseeing the exact distance at which the enemy will be when an opportunity may occur for delivering the fire, the greater concentration between 100 and 400 yards is more than counterbalanced by the increased spread beyond that range.

Comparing the concentrations for 900 and 600 yards it will be seen that up to about 700 yards a small advantage lies with the latter, while beyond that distance the former will be most effective. In central battery ships, where the guns are close together, the lateral error will be smaller than that shown in the figure, and remembering that great accuracy is not to be expected from broadside firing, the simplicity which is obtained by the use of one fixed distance more than counterbalances this objection.

As regards the horizontal plane the choice seems to lie between 600 yards and some greater distance.

**As regards vertical plane.**

As regards the vertical plane, a study of the tables and curves given on pp. 130, 272–291 shows that an average service gun converged so as to strike an enemy's ship at a point 10 feet above the water line at a distance of 600 yards would, so far as elevation is concerned, strike an object of the height of 20 feet at any distance short of 800 yards, with a certain margin for errors in pointing.

This distance of 600 yards is, however, the farthest at which such would be the case, but an increase in the flatness of the trajectory would enable this standard distance to be increased; and considering the recent great improvements made by private gun makers in the manufacture of ordnance, it may be hoped that before long this may be done.

Also by placing the director a certain height above the guns, the effect of an error in estimating the distance is reduced, as the error in the dip tends to counteract the error in elevation. This is especially the case at probable fighting ranges. *See* table, p. 213.

These considerations have led to the adoption of 600 yards as the distance at which to converge the broadside horizontally.

In the vertical plane the guns would always be laid for the elevation due to the fixed distance, but if just before delivering the fire it should be found that the actual distance of the enemy differs considerably from this, the sight of the director may be altered.

Under the above limitation of distance the broadside would however be fairly accurate without this, and making altera-

tions at the last moment should never be attempted unless the officer at the director has perfect confidence in himself.

(3.) It is considered that this number of bearings will cover all the requirements of service. The bow and quarter points should be marked for the extreme bearing on which the guns can be laid at the fixed distance, and 15° is taken for the intermediate point as nearly equally dividing the space. Reasons for five bearings.

It would be a good plan if guns secured on the beam were fitted so that when secured they were converged on the beam bearing.

The director would be marked for these fixed bearings, the correction for distance being allowed, so that the only variable would be the speed of the ship, and even that could probably be fixed on the horizontal correction arc before going into action.

Some mechanical means, such as a sliding clamp or spring, might also be fitted, so that when it fell into the notch corresponding to the named bearing, the adjustment of the director would be correct.

(4.) A mark across the racer like that at present used as a "ramming mark," or if mechanical means be used, a hole or otherwise in the racer, would be all that was required for this purpose. Marks for bearings.

Various suggestions have been made as to fixing the guns on the bearings provided; rearbolts and flaps, drop bolts, skids for rear rollers, &c. have been suggested, but it seems that the most simple plan is that mentioned above.

(5.) The degrees on the racer would frequently be used in the other firings in order to point out the direction of an object at which it is desired to fire, but, for the reasons given above, should not be used for concentrating, and the correction tables should accordingly be done away with. Marking in degrees.

The plan mentioned has been adopted, and in future the concentrating marks will be fitted in the dockyards for the one distance, and the five bearings given on page 192.

When, however, the captain of any ship considers that the men are sufficiently well trained to be able to employ a more complicated method, without probability of failures, other marks may be added for distances of 400 and 800 yards. These three distances would cover all the requirements of service. Exceptional circumstances.

Ships now in commission similarly may adopt the one distance plan if considered desirable, but in any case separate marks for 200 and 300 yards should not be retained.

## RACERS.

How racers are laid.

RACERS have been laid in ships in one of the following ways:—

1. Following the slope of the deck, both in the fore-and-aft and athwartship planes; so that when the ship is upright and at her sea trim, the plane of the racers is not horizontal in any direction.
2. Horizontal in the fore-and-aft line only, when the ship is upright and at her sea trim; but otherwise, with the plane so inclined that there is a slope towards the ship's side of from $1\frac{1}{2}°$ to $2°$.
3. Horizontal in every direction, when the ship is upright and at her sea trim.
4. As in (3), but with the front racer vertically lower than the rear one, so that there is an inclination from all parts of the rear racer downwards to the front racer of from $1\frac{1}{2}°$ to $2°$.

Advantages and disadvantages.

With reference to these various methods, it may be remarked that the advantages of inclining the racers in the athwartship direction are that—

*a.* The recoil is slightly diminished.

*b.* The front racer need not be blocked up at the ends.

The disadvantage is that the director must be fixed at the same inclination, which leads to some complications, as will be hereafter explained. A very slight inaccuracy in laying by sight is also introduced when the guns are off the beam, which is, however, of no practical importance.

The disadvantage of laying the racers horizontal in the fore-and-aft direction are that the after ends are blocked up so as to become obstructions. The advantages are that the fire will be very slightly more accurate, and that the guns will in some positions be more easily trained.

Best method.

The most accurate method is to have the racers laid horizontal in all directions, but where the sheer of the deck is considerable then no practical objection exists to their following it in the fore-and-aft direction, being kept, however, horizontal athwartship.

Unless otherwise stated it will be assumed throughout the rest of this chapter that this latter condition has been fulfilled.

Graduation in degrees.

Rear racers will in future be graduated in degrees on their outboard edges from 0 to as many degrees as the gun can be trained, the zero mark being so placed that when the pointer on the slide is brought on with it, the axis of the gun is at right angles to the fore-and-aft line, and every 5°

being numbered, with the intermediate degrees simply lined in.

They have been further subdivided to $\frac{1}{4}°$, but this is not necessary, and will no longer be done.

In some cases it may be more convenient to mark the inboard edge, as being nearer to the captain of the gun.

Concentrating marks.

Concentrating marks are also to be placed at the several bearings of a beam, 15° before and abaft, on the bow and quarter, as explained on p. 192.

## CALCULATIONS.

### *Preliminary.*

True fore and aft line.

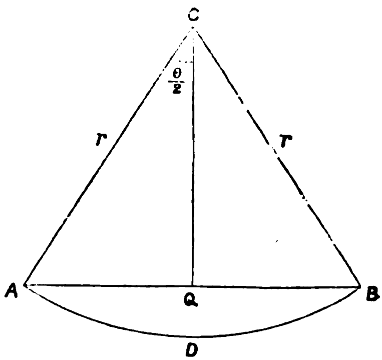
A line joining the centres of any two midship stanchions or hatchways gives the true centre line, and this may be transferred to any part of the deck by describing arcs of equal radii from each of its extremities, and drawing a line touching both.

The length of the chord of an arc can be found thus :—

Length of chord of arc.

Let AQB be the chord of an arc ADB, which subtends an angle $\theta$ ($=$ACB) at a radius AC ($=r$).

Fig. 2.




Draw CQ perpendicular to AB,
Then chord $AQB = 2 \times AQ$

$$= 2AC \times \sin ACQ$$
$$= 2AC \sin \frac{ACB}{2}$$
$$= 2r \sin \frac{\theta}{2};$$

or the length of the chord of an arc is equal to the radius multiplied by twice the sine of half the corresponding angle.

When $\theta$ is small, calculations may be simplified by remembering that when $r$ equals one foot, the length of the chord for one degree is ·21 inch.

Division of arc into degrees.

To divide an arc into degrees.—Find the length of the chord which subtends any small angle, say 5°, and by means of it divide the arc into equal parts of 5°, which further subdivide into degrees, half degrees, or smaller angles.

Marking racers in degrees.

To mark a racer in degrees.—From the pivot in the port let fall a perpendicular on the fore-and-aft line drawn at any convenient distance in rear of the racer. From this perpendicular

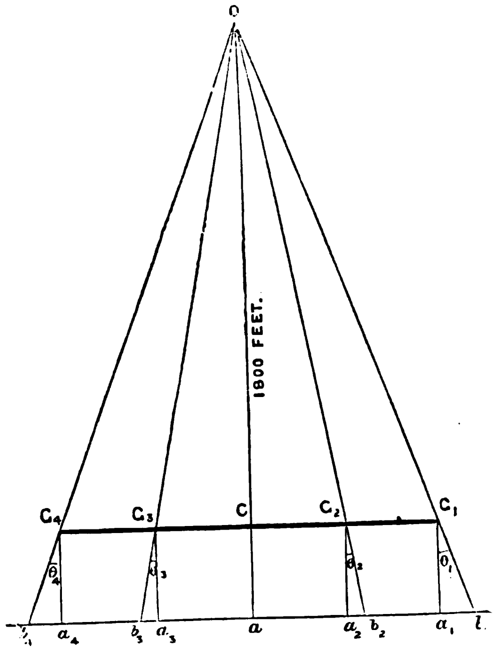
Marking racers.

set off by means of a T square the perpendicular distance of the centre of the slide from the pointer and mark where the edge of the racer corresponds to this distance for the zero mark of the graduations. From this point divide the arc into degrees in the manner before explained.

### *Converging broadside Guns.*

As before explained the concentrating marks are to be placed for five bearings at a fixed distance of 600 yards. Their position can be easily calculated, as will be seen by reference to the figures below.

Fig. 3.




...ulations for the beam.

First, when concentrating on the beam—

In Fig. 1, O is the object distant 600 yards from C the pivot of the centre gun;

$G_1$, $G_2$, $G_3$, &c. are the pivots of the remaining guns;

$\theta_1$, $\theta_2$, $\theta_3$, &c. the corresponding bearings; which can be easily calculated, since the distances $CG_1$, $CG_2$, &c. can be ascertained by direct measurement.

These bearings can, if the racers are already marked in

degrees, be made use of to find the concentrating marks. It will, however, be generally more simple to proceed as follows:— **Calculations for the beam.**

Get a fore-and-aft line at a convenient distance from the pivots, say 15 feet. From the pivots set off perpendiculars to this line, intersecting it at $a_1$, $a_2$, $a_3$, &c., from which measure off the distances $a_1b_1$, $a_2b_2$, &c. Strike lines through $G_1B^1$, $G_2B_2$, &c., and we have the positions of the axes of the guns.

The racer is then marked as mentioned above.

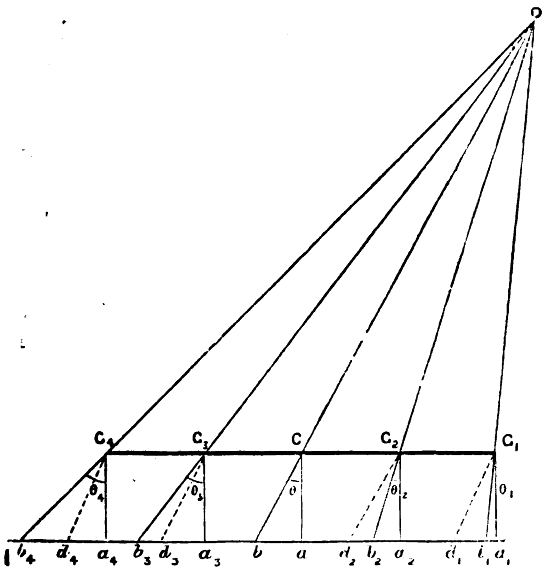
The lengths $a_1b_1$, $a_2b_2$, &c. are very simply obtained, since

$$\frac{a_1b_1}{a_1\,G_1} = \frac{CG_1}{OC}.$$

$$\therefore a_1b_1 = CG_1 \times \frac{15}{1{,}800}.$$

$$= \frac{\text{distance from centre gu}}{120}.$$

Fig. 4.




Second, when concentrating off the beam— **Calculation o' the beam.**

Similarly in Fig. 4, the bearings can also be readily calculated, since the angles at C are known, as also the distance CO and $CG_1$, $CG_2$, &c.

As in the last case it will be generally more simple to measure off the distances $ab$, $a_1b_1$, &c. along a fore-and-aft

Calculations off the beam.

line. The determination of these lengths is slightly more complicated, and is as follows:—

Determine $ab$ the length for the centre gun. This is given by $ab = ac \tan \theta$.

Then for any other gun, as $G_3$:

Since the dotted lines $G_1d_1$, $G_2d_2$, &c. are drawn parallel to $Cb$

$$a_3b_3 = a_3d_3 + b_3d_3 = ab + b_3d_3,$$

or for a gun the other side of the centre gun,

$$a_2b_2 = a_2d_2 - b_2d_2 = ab - b_2d_2.$$

Now $b_3d_3$ or $b_2d_2$ can be easily determined,

$$\text{since } \frac{b_3d_3}{G_3d_3} = \frac{G_3C}{CO} \text{ by similar triangles;}$$

$$\therefore b_3d_3 = \text{dist. from centre gun} \times \frac{CO}{Cb}$$

## *Converging Turret Guns.*

Position of marks.

Marks should be placed round the outside circumference of the turret, overhead, to indicate the different angles of training before and abaft the beam.

The zero marks should correspond to the position of a pointer, fixed in some convenient position, when the axes of the guns are at right angles to the fore-and-aft line of the ship.

In order to converge the turrets, so as to fire by director, certain bearings as 0°, 15°, 30°, 45° before and abaft the beam are selected, and the corresponding angles for the turrets are calculated for the distance of 600 yards as in concentrating broadside guns.

Marks are placed at these calculated bearings as at broadside guns.

## *Elevating and heel Scales.*

Elevating scale.

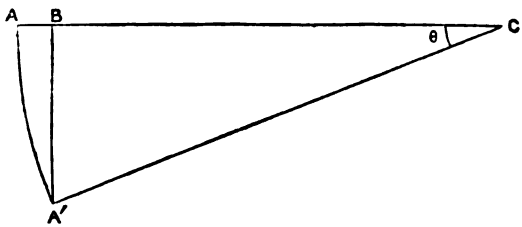
The wood scale is a long piece of wood, square in section, and provided with a movable slide fitted with a pointer and clamping screw.

It is graduated in degrees and quarter degrees, also in yards, but this last graduation is no longer used for broadside guns, and only for turret guns when the old sights are in use.

There is no apparent reason why the elevating arc of broadside guns should not be graduated in degrees, &c., and a pointer fitted, the wood scale being done away with.

To calculate the length of the several degrees on the scale :— Calculation.

Fig. 5.




Let C be the centre of trunnions.

AC the axis of gun when laid horizontal.

A′C the axis of gun when elevated for an angle $\theta$; A′ being in that case the zero mark on the heel scale.

Then for any angle of elevation $\theta$, A′B is the amount the pointer on the scale must be lowered.

Now $A'B = A'C \times \sin\theta =$ distance of centre of trunnions from the rear face of cascable $\times$ sine of the angle of elevation.

When the radius A′C or AC does not exceed 40 in., the length A′B is found for the highest angle of elevation, and subdivided for each degree. When A′C is more than 40 in., the length of each degree is calculated separately.

After the wood scales are supplied, they have to be cut to length, and then clearly marked for the gun they belong to. Cutting the scales.

To cut a scale, lay the gun horizontal (the ship being upright), and adjust the pointer to correspond with the zero on the heel scale. The distance from the pointer to the zero mark on the wood scale is the amount which must be cut off the bottom of the scale.

The use of the scale is to measure the angle of elevation or depression of a gun above or below the plane of the racers, or to give a gun any desired amount of elevation or depression above or below that plane. Use.

The heel scale was used in combination with the elevating scale to give the gun any desired elevation above a plane passing through the gun and the object. It is now no longer used except in some turret ships. Heel scale.

## The Director.

### *Description.*

The director consists of two principal parts.

Principal parts. (1.) The horizontal arc, and (2), a support carrying a telescope working on trunnions and provided with vertical correction arcs and verniers.

The horizontal arc is a semicircular frame graduated in degrees and 20′ from 0° to 90° each way, representing bearings before and abaft the beam. All the graduated arcs of the instrument are divided in this way as far as their length permits.

At the centre of the semicircle is a projecting pivot, on which the support carrying the telescope ships.

Arrangement of horizontal verniers. This support has a long arm, or radius bar, the end of which, forming an open frame, moves over the graduated horizontal arc, and is provided with a movable slide on which are cut two verniers; one to read off bearings on the horizontal arc, and the other to be used in conjunction with a correction scale, fixed to the extreme end of the arm on top, so that the pointer of the first vernier can be set at any angle to the axis of the telescope up to 6° each way. The arm or radius bar is provided with a clamping screw to the horizontal arc, and the sliding verniers with one to the radius bar. The correction scale is graduated to 6° each way, the zero mark being in the centre of the end of the radius bar, and it is used for allowing the necessary horizontal corrections, as will be explained hereafter.

Stop. A spring stop is fitted in some directors, and will be fitted in all, to correspond to the stops on the racers mentioned on p. 192.

Verniers. All the verniers of the instrument are alike, and consist of simply a pointer with a line 30′ on each side of it, so that readings can be readily taken to 10′ and by eye to 5′.

Telescope. The telescope works on trunnions on the support, the axes of the trunnions being immediately over the centre of the pivot, and the axis of the telescope parallel with a line drawn through the centre of the pivot and the zero mark of the horizontal correction scale on the radius bar.

Arrangement of vertical arcs. The rear end of the telescope carries a vernier, and by means of a rack and pinion arrangement it can be readily elevated or depressed through an arc of about 10° each way. Between the vernier of the telescope and the bracket of the support on the left there slides a movable vertical arc, graduated for 10°

each way on the right side, or that next the telescope, and provided with a clamping screw to clamp it to the telescope, so that both may be raised or lowered by the rack and pinion together. On the left the arc is graduated to 10°, but only in one direction, viz., downwards, and there is also a clamping screw through the support to clamp the movable arc to the latter when required. Arrangement of vertical arcs.

The left bracket of the support is also provided with a vernier to read off angles on the left of the vertical arc. These verniers are so placed that if the vertical arc be clamped at zero to the support, and the telescope also clamped at zero to the arc, then the axis of the telescope is parallel to the plane of the horizontal arc.

On the top of the telescope is also a sliding rod sight for use at night, or to get bearings, &c. on with roughly.

Every instrument should be tested to ascertain that the cross wires are so placed that the line of sight is in the centre of the field. Test for accuracy.

## *Position.*

The position in which the director should be placed depends on—

1. The means of communication with the helm, engine room, and gun decks.
2. The position where the clearest possible view of any object on which the guns can be concentrated is obtained.
3. Where the maximum amount of protection from the enemy is afforded.
4. The position of the directing (usually the midship) gun of the broadside.

This position having been settled, it is to be fixed as follows:— How to be fixed.

1. The axis of the telescope, when the radius bar is clamped at zero, is to be at right angles to the fore-and-aft line.
2. The plane of the semicircular arc is to be parallel in every direction to that of the racers on which the guns work (*vide* p. 212).

As the director is actually the sight of the guns, it should always be kept in place, the greatest care being taken to prevent it being put out of adjustment. To be kept shipped.

A cover is to be fitted to protect it when not in use.

In some ships the table on which the director is placed is fitted with vertical screws by which the plane of the instru- When fitted with vertical screws.

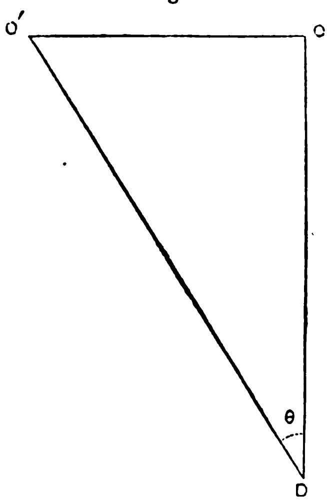
ment can be altered vertically. Where this is the case great care must be taken to preserve them from interference, and it will be found a good plan to fit a set screw, which, when screwed up hard, will prevent the adjusting screw from moving.

*Corrections.*

These are—

1. Correction due to the speed of the ship.
2. Correction due to the height of the director above the axes of the guns.

Fig. 6.




Speed correction.

1. To find the correction due to speed.

Let D represent the position of the director;

O, the position of the object;

OO′, the distance to the left of the object it is necessary to point in order to hit it.

Now $OO' = \dfrac{\text{speed} \times \text{time of flight}}{3{,}600}$.

Error in feet.

TABLE showing the Values of OO′ in *Feet* due to various Speeds and Times of Flight.

| Times of Flight. | Speed in Knots. | | | |
|---|---|---|---|---|
| | 5 | 10 | 15 | 20 |
| sec. | | | | |
| 1 | 8·4 | 16·9 | 25·3 | 33·8 |
| 1·25 | 10·5 | 21·1 | 31·5 | 42·0 |
| 1·5 | 12·6 | 25·2 | 37·8 | 50·4 |
| 1·75 | 14·7 | 29·4 | 44·1 | 58·8 |
| 2·00 | 16·8 | 33·8 | 50·6 | 67·6 |

$$\text{Also } \tan\theta = \frac{OO'}{OD} = \frac{\text{speed} \times \text{time of flight}}{3{,}600 \times \text{distance}}.$$

TABLE showing the correction to be applied to the Director for various Speeds and Times of Flight for a distance of 600 yards. Correction.

| Times of Flight. | Speed in Knots. | | | |
|---|---|---|---|---|
| | 5 | 10 | 15 | 20 |
| sec. | ′ | ° ′ | ° ′ | ° ′ |
| 1·00 | 16 | 0 32 | 0 48 | 1 4 |
| 1·25 | 20 | 0 40 | 1 0 | 1 20 |
| 1·5 | 24 | 0 48 | 1 12 | 1 36 |
| 1·75 | 28 | 0 56 | 1 24 | 1 52 |

This correction is for the speed of your own ship, is applied to the right or left, according as the director is on the port or starboard side, and may be used for all ranges within which director firing would be used.

TABLE showing the Times of Flight for various Guns, and assumed Velocities. Times of flight.

| Guns. | M. V. | Distance in Yards. | |
|---|---|---|---|
| | | 600 | 800 |
| | f. s. | sec. | sec. |
| 12·5 in. 38-ton - - | 2,000 | 0·93 | 1·24 |
| „ „ - - | 1,700 | 1·09 | 1·46 |
| „ „ - - | 1,400 | 1·32 | 1·77 |
| „ „ - - | 1,200 | 1·54 | 2·07 |
| 7-in. $6\frac{1}{2}$-ton - - | 2,000 | 0·95 | 1·29 |
| „ - - - | 1,700 | 1·12 | 1·52 |
| „ - - - | 1,500 | 1·27 | 1·72 |
| „ - - - | 1,200 | 1·57 | 2·13 |

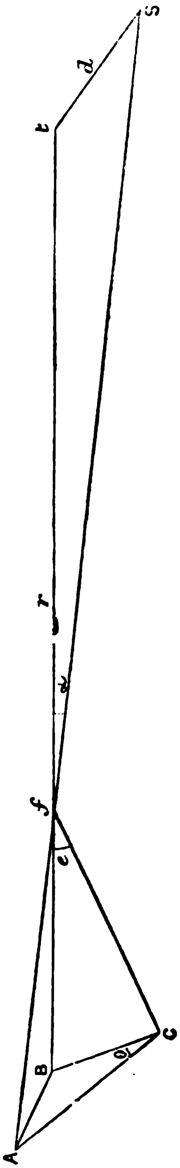
From an inspection of these tables it is thought that, with the velocities of the guns now afloat, it will be sufficient to use the speed correction for the heaviest charge used.

When the horizontal correction arc is graduated in degrees, &c. it will be necessary to have a table, as below, showing the correction due to the normal fighting speed and to speeds differing by four or five knots. Correction table.

| Speed Correction. | |
|---|---|
| Speed. | Correction. |
| | ° ′ |
| 5 | |
| 10 | |
| 15 | |
| 20 | |

pring stop.

When the spring stop before mentioned is fitted, it should be adjusted according to this table, but there appears to be no reason why the director should not be marked in knots for each ship and for each side, in which case the table would not be required, as the stop would be set to the corresponding speed.




;orrection due
› drift.

It is sometimes advocated that a correction should be applied due to the drift of the projectile.

This can be calculated as follows :—

Let C represent the bottom of the hind sight raised CB or CA, B being the top supposing the sight to be vertical, A when inclined.

Let $\theta$ = inclination of sight = ACB
„ $d$ = drift „ = $ts$
„ $r$ = range „ = $tf$
„ $e$ = angle of elevation = $cf$A
„ $\alpha$ = angle $tfs$ the correction angle required, due to the drift $ts$.

$$\text{Now, } \frac{ts}{tf} = \frac{AB}{Bf} \text{ or } \frac{d}{r} = \frac{BC \tan\theta}{BC \operatorname{cosec} e}$$

$$\text{or } \tan\theta = \frac{d}{r} \operatorname{cosec} e.$$

$$\text{And } \tan\alpha = \frac{ts}{tf} = \frac{d}{r} \text{ and}$$

$$\therefore \operatorname{Tan}\alpha = \tan\theta \cdot \sin e$$

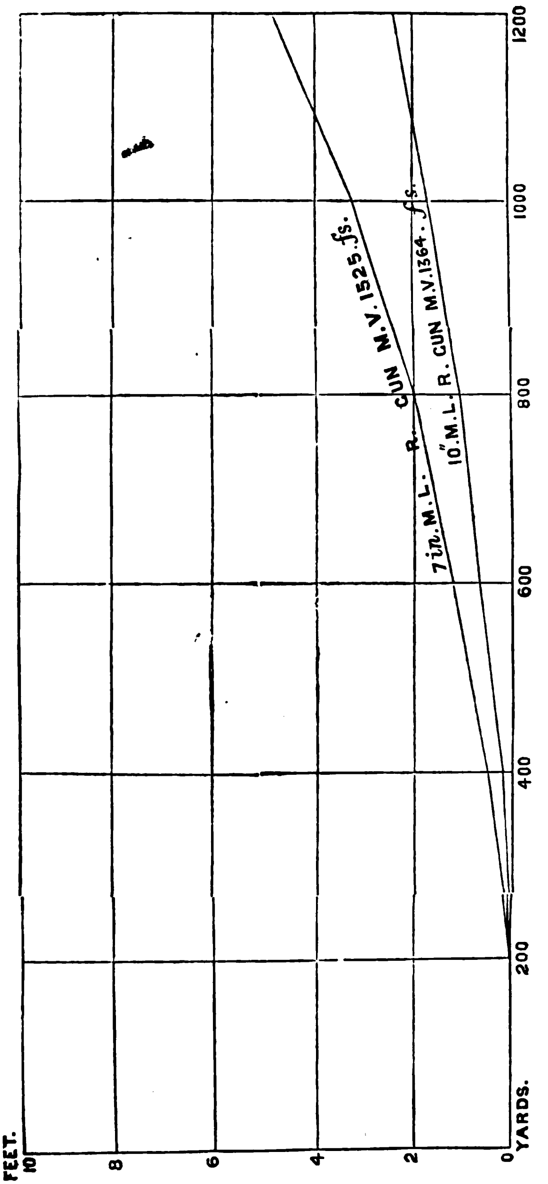
from which $\alpha$ can be found.

Iot practically
ıportant.

Now $\alpha$ is the correction required, and varies very slowly with the distance. When used it is allowed to the left, but as is shown in Fig. 9, its amount is so small as to be of no practical importance within the limits within which the director would be used.

Fig. 9.

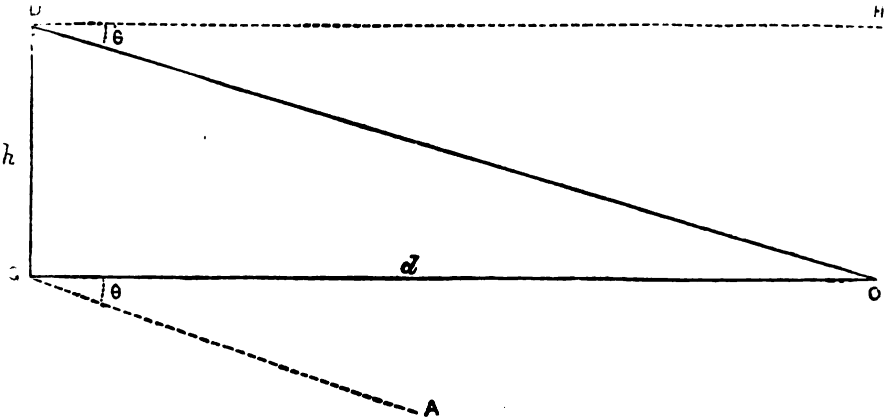
Diagram showing Error due to Drift.



Correction due to height above guns.

2. To find the correction due to the height of the axis of the director above that of the centre gun.

Fig. 10.




Let D represent the position of the director at a height $h$ above the centre gun G.

Let O be the object at a distance $d$.

It is required to find the vertical correction HDO, or $\theta$, (= DOG), which must be applied to the director in order that its line of sight may intersect the line of sight of the gun at the object O.

$$\text{Now } \tan\theta = \frac{h}{d} = \frac{\text{height of director above directing gun.}}{\text{distance of the object}}$$

Since $h$ is constant $\tan\theta$ varies inversely with the distance.

Consequence of not applying.

If this correction were not applied, the shots from the guns would evidently fall short; for suppose the lines of sight of the gun and director to remain parallel, as GO, DH, and the ship to heel or roll over, so as to bring the line of sight of the latter on with the object; it is evident that the line of sight of the former would be directed at an angle $\theta$ below GO as GA.

Method of allowing for.

Until recently the custom has been to keep this correction on a table by itself and to apply it alone to the left hand or dip scale of the movable arc, in a manner that will be hereafter explained; but the best method is to combine it with the elevation for the particular distance and charge, and to tabulate them as follows :—

| Distance in Yards. | Corrected Elevation. | |
|---|---|---|
| | Battering. | Full. |
| | ° ′ | ° ′ |
| 200 | | |
| 300 | | |
| 400 | | |
| 500 | | |
| &c. | | |

If the directors were marked for each ship, and one charge used, then it would be advantageous to graduate the elevation arc in yards, and thus do away with the vertical correction table.

*To verify the Accuracy of the Director and Concentrating Marks.*

1st. Ascertain whether the axis of the telescope is at right angles to the fore-and-aft line of the ship, when the radius bar is clamped at zero. To do this, select by means of the azimuth compass some well defined and distant object on the beam, or a near object whose distance is known, and, in the latter case, applying to the director the beam correction due to its distance from the compass; now ascertain if the line of sight of the director is on with the object, when the horizontal reading is zero. Telescope at right angles fore-and-aft line.

2nd. Ascertain that the converging marks are correct and that they agree with the director. This can be done by comparing the angles at which the marks are placed with those as calculated, or by laying guns and director for some object as in (1.). Accuracy of converging marks.

3rd. Ascertain that the wood scales are correct. If the ship is quite steady lay the guns with the sights close down for a well defined and distant object, and measure off the elevation by scale. The readings on the scales should agree with one another, and with the inclination of the ship. Correctness of wood scales.

If buildings, &c., prevent the selection of a distant object, then one or more points *in the same plane* as the guns must be selected.

If the ship is not quite steady, each gun must be compared separately with the directing gun.

Another method is to lay the guns horizontal by spirit level, in which case the elevation by scale should agree with the inclination of the ship.

Parallelism of director and racers.

4th. Ascertain that the plane of the director is parallel to that of the racers.

The directing gun and the director must be laid—1. For an object on the beam. 2. For an object off the beam, and the readings compared. If a near object is selected, it should be in the same horizontal plane as the gun, and the director laid for a point higher by the distance the director is above the axis of the gun.

This may also be done by spirit level.

If the plane of the racers is not horizontal athwartships when the ship is upright, the plane of the director being parallel to it will also not be horizontal. In order to make the zero point on the vertical arc of the director agree with that on the elevating scale, which is cut so that the gun may be horizontal when laid to zero, a contant correction has to be applied at the director.

## *Method of using the Director.*

Method of use.

When the officer in command orders a broadside to be prepared, the officer at the director communicates the order to the battery, naming the bearing, and at the same time adjusts for the speed and fixes the radius bar at the named bearing. He then takes from the table the "corrected elevation" due to the distance, and sets the movable arc to this by means of the left scale and vernier, moving the arc if necessary by the rack and pinion, the telescope being clamped to the arc. The arc is now clamped to the support, and the clamping screw between it and the telescope being loosened, the latter is aligned for the object, or for the point where it is estimated it will pass, consideration being given to the motion of the ship; the telescope is then clamped to the arc, and the elevation or depression shown on the right graduation of it read off and passed to the guns, which are laid by scale and brought to the "Ready." The clamping screw between the arc and support may now be loosened, but it is to be distinctly remembered that the relative positions of the telescope and movable arc are on no account to be altered without a fresh elevation or depression being passed to the guns.

Alteration of distance.

Should the distance of the object alter before the sights come on, the new corrected elevation may be rapidly put on the left scale of the movable arc by means of the rack and pinion, the telescope being depressed or raised according as the distance has increased or diminished, and the broadside

fired when the motion of the ship brings the sights on. This is one of the great advantages of using the director in this manner.

It should be remembered that the helm exercises great influence on the heel of the ship. Helm.

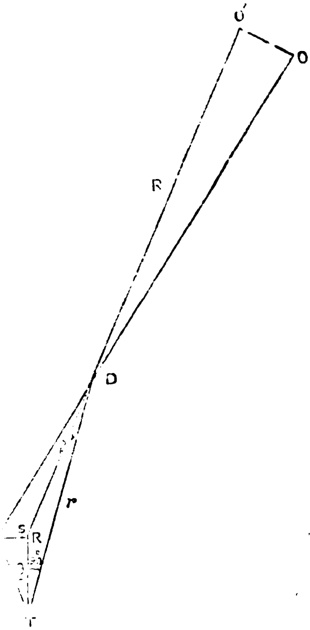
Allowance for wind and speed of the enemy are best allowed for by firing a little to windward or ahead. Wind and speed of enemy.

## Errors.

Racers not horizontal.

*To find the error due to the sight being inclined, owing to the plane of the racers not being horizontal when the ship is at her sea trim.*

Fig. 11.



Let TS represent the sight when upright.

„ TS′ when inclined to any angle $\theta$.

„ $\alpha$ be the angle the sight is raised to.

„ O be the object.

„ SDO′ the line of fire.

S′DO is the line of sight and S′R the perpendicular from S′ on TS.

Then SR = loss in elevation;

And S′R is the horizontal change in position of the top of the sight due to its being inclined at an angle $\theta$.

Now $S'R = S'T \sin\theta = ST \sin\theta = r \tan\alpha \sin\theta$ - (1)

where $r$ = the distance between the sights

And $SR = ST - RT = ST\,(1 - \cos\theta) = 2\,ST \sin^2\frac{\theta}{2}$.

$$= 2\,r \tan\alpha \sin^2\frac{\theta}{2} \qquad (2)$$

Let D be the top of the foresight.

Then OO′ is the distance the shot will fall to the left of the object O.

$$\text{Now } \frac{OO'}{OD} = \frac{S'R}{S'D} \text{ and}$$

$$S'R = r \tan \alpha \sin \theta \quad - \quad - \quad \text{from (1).}$$

$$S'D = r, \text{ and } OD = \text{range};$$

$$\therefore OO' = \text{range} \tan \alpha \sin \theta$$

$$\text{or error in direction} = \text{range} \times \tan \alpha \sin \theta$$

$$\text{also error in elevation} = \tan^{-1} \frac{SR}{r} = \tan^{-1} 2 \tan \alpha \sin^2 \frac{\theta}{2}.$$

$$\text{Taking range} = 3000 \text{ feet}, \alpha = 1^\circ 23', \theta = 1^\circ 30'$$

$$\text{Error in direction} = 1{\cdot}89 \text{ feet}$$

$$\text{,, \quad elevation} = \text{about } 10''.$$

Director not parallel to racers.

*To find the error in elevation due to the plane of the director not being parallel to the plane of the racers.*

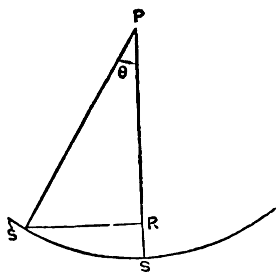



Fig. 12.

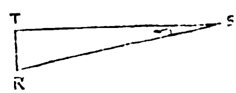



Fig. 13.

Let P be the pivot in the port (Fig. 12).

,, S the position of the scale when the gun is trained abeam.

,, S′ the position of the scale when the gun is trained $\theta$ degrees before or abaft the beam.

Draw S′R perpendicular to PS,

Then the slide, gun, and scale have all moved a little down the incline of the racer SR.

The amount can be represented vertically by TR (Fig. 13).

Then from Fig. 12 we have—

$$SR = SP - PR = SP - SP \cos \theta$$

$$= SP\,(1 - \cos \theta) = 2\,SP \sin^2 \frac{\theta}{2}$$

Now from Fig. 13 we have—

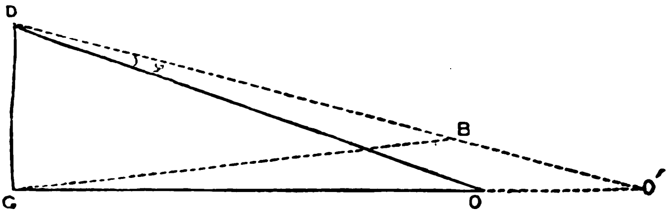
$$TR = SR \sin \alpha$$

$$\therefore\ TR = 2\,SP \sin \alpha \sin^2 \frac{\theta}{2}.$$

The length TR being found, the amount of error in elevation can be easily read off the scale.

*To find the change in elevation due to the object passing at a distance other than that for which the broadside is prepared.* Distance incorrect.

Fig. 14.




Let D be the director;

G the centre gun directly underneath;

GO the distance for which the broadside is converged;

GO′ the distance of the object when fired at.

Then evidently the line of sight is raised through an angle ($\phi$) = ODO′, and the axes of the guns are also elevated through the same angle. These angles ($\phi$) have been calculated and are shown in the annexed tables, together with the resulting angles of elevation with reference to the plane through the gun and object, which are obtained by simply combining the value of $\phi$ with the elevation due to the distance.

Director 15 Feet above Axes of Guns.

| Adjustments made and Guns laid for | Change in elevation ($\phi$), if the object passes at | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1,000 | 1,100 | 1,200 |
| 400 - - | −129 | −43 | −14 | 0 | + 9 | +15 | +19 | +22 | +24 | +26 | +28 | +29 |
| 600 - - | −144 | −58 | −29 | −15 | − 6 | 0 | + 4 | + 7 | + 9 | +11 | +13 | +14 |
| 800 - - | −151 | −65 | −36 | −22 | −13 | − 7 | − 3 | 0 | + 2 | + 4 | + 6 | + 7 |
| 1,000 - - | −156 | −69 | −40 | −26 | −17 | −11 | − 7 | − 4 | − 2 | 0 | + 2 | + 3 |
| | Resulting angles of elevation 10″ gun Bat. charge. | | | | | | | | | | | |
| 400 - - | −93 | − 7 | +22 | 36 | 45 | 51 | 55 | 58 | 60 | 62 | 64 | 65 |
| 600 - - | −88 | − 2 | +27 | 41 | 50 | 56 | 60 | 63 | 65 | 67 | 69 | 70 |
| 800 - - | −75 | +11 | 40 | 54 | 63 | 69 | 73 | 76 | 78 | 80 | 82 | 83 |
| 1,000 - - | −58 | +28 | 57 | 71 | 80 | 86 | 90 | 93 | 95 | 97 | 99 | 100 |

### Director 10 Feet above Axes of Guns.

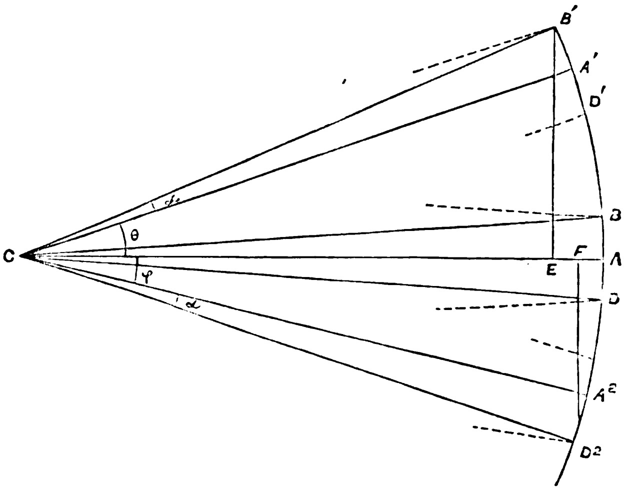
| Adjustments made and Guns laid for | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1,000 | 1,100 | 1,200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Change in elevation ($\phi$) if the object passes at. | | | | | | | | | | | |
| 400 | − 85 | −28 | − 9 | 0 | + 6 | +10 | +13 | +15 | +16 | +17 | +18 | +19 |
| 600 | − 95 | −38 | −19 | −10 | − 4 | 0 | + 3 | + 5 | + 6 | + 7 | + 8 | + 9 |
| 800 | −100 | −43 | −24 | −15 | − 9 | − 5 | − 2 | 0 | + 1 | + 2 | + 3 | + 4 |
| 1,000 | −102 | −45 | −26 | −17 | −11 | − 7 | − 4 | − 2 | − 1 | 0 | + 1 | + 2 |
| | Resulting actual angles of elevation 10″ gun Bat. charge. | | | | | | | | | | | |
| 400 | −49 | + 8 | 27 | 36 | 42 | 46 | 49 | 51 | 52 | 53 | 54 | 55 |
| 600 | −39 | +18 | 37 | 46 | 52 | 56 | 59 | 61 | 62 | 63 | 64 | 65 |
| 800 | −24 | +33 | 52 | 61 | 67 | 71 | 74 | 76 | 77 | 78 | 79 | 80 |
| 1,000 | − 5 | +52 | 71 | 80 | 86 | 90 | 93 | 95 | 96 | 97 | 98 | 99 |

## Dimensions of Ports.

Height of port required.

*To find the height of port necessary for a given amount of elevation and depression, so that the gun may just recoil in clear of it.*

Fig. 15.




Let C be the centre of the trunnions;

$AB = A^1B^1 = AD = A^2B^2 =$ semidiameter of the gun at the muzzle;

$A^1CB^1 = A^2CD^2 = \alpha =$ angle subtended at centre of trunnions by semidiameter at the muzzle;

$A^1CA =$ angle of elevation $= \theta$;

$A^2CA =$ angle of depression $= \varphi$.

Evidently height of port required $= EB' + FD^2$.

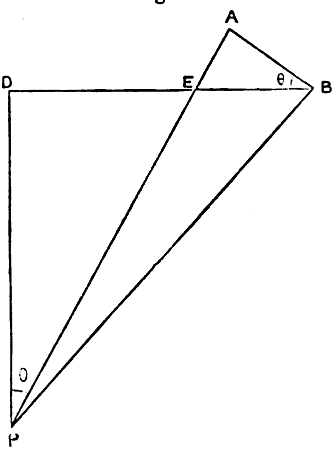
Now $\tan \alpha = \dfrac{A^1B^1}{A^1C}$. Also $B^1C = A^1C, \sec \alpha$.

Hence we find $\alpha$ and $B^1C$.

$$\text{Height of port} = EB^1 + D^2F$$
$$= B^1C \sin \overline{\theta + \alpha} + D^2C \sin \overline{\varphi + \alpha}$$
$$= B^1C (\sin \overline{\theta + \alpha}, + \sin \overline{\varphi + \alpha})$$
$$= 2\, B^1C \sin \frac{\theta + \varphi + 2\alpha}{2} \cos \frac{\theta - \varphi}{2}.$$

*To find the width of port necessary to allow a given angle of training.* Width of port.

Fig. 16.




Let D be the centre and DB half the width of the port.

Let P be the pivot and PA the axis of the gun.

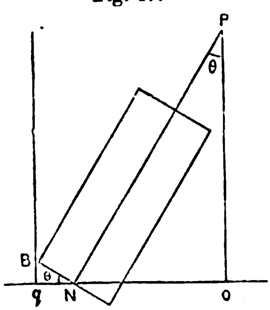
Let AB be the radius of the gun at the port when run out and trained through an angle $\theta = DPA$ or $ABE$.

Let PD be the distance of the pivot from the centre of the port;

Then DB, or half the width of port $= DE + EB$
$$= PD \tan \theta + AB \sec. \theta;$$
or whole width of port to allow $\theta$ degrees of training each way $= 2\,(PD \tan \theta + AB \sec \theta.)$

*To find the distance necessary between ports to admit a certain angle of training.* Distance between decks.

Fig. 17.




Let P be the pivot in the port;

PO the axis of the slide when trained abeam;

PN the axis of the slide when trained $\theta$ degrees from the beam;

BN half the width of slide; and

OQ ½ distance between ports.

Then $OQ = ON + NQ$
$$= PN, \text{Sin } \theta + BN, \cos \theta,$$
or the distance between the ports to admit of training the guns independently $\theta$ degrees each way $= 2\,(PN \sin \theta + BN \cos \theta)$.

Depression required.

The lower port sill being fixed, the height of the axis of the gun depends upon the amount of depression necessary, which again varies with the ship, since it should be possible to lay the guns horizontal in any probable position of the ship when not under sail. We may assume that under ordinary circumstances no ship should heel more than 7°, and therefore the position of the axis of the gun, with reference to the lower port sill, should be such as to allow of 7° depression. The distance from the ship at which the shot would strike the water when the guns are depressed and the ship upright, should also be considered.

Elevation required.

The minimum amount of elevation which a port should allow depends upon the following points:—

(1.) It should be possible to lay the guns in any position of the ship, when not under sail, at an object at fair fighting range. Taking the same heel as before, and object at 2,000 yards, this would give rather over 10° elevation.

(2.) Where the ship is upright it should be possible to lay the guns for a range of at least 5,000 yards.

(3.) A good view of the object should be afforded.

# CHAPTER X.

## ASCERTAINING THE DISTANCE OF AN OBJECT AT SEA.

### Various Methods.

Sir Howard Douglas's method, in which an observer on deck ascertains with a sextant the angle subtended by the enemy's masthead and hammock netting or water line, can only be used when the height can be approximately estimated. Sir Howard Douglas.

It is essential to its accuracy that the triangle be right-angled or nearly so; thus, if observing from a boat, the water line of the ship should be taken as the far end of the base, and if from a ship's bridge or poop, the hammock netting. The heights of the ships' masts from main truck, cross-trees, and lower masthead to the hammock netting should be ascertained and tabulated in each squadron.

At any favourable opportunity the heights of foreign ships' masts should also be ascertained and recorded (see case 4, p. 219.)

This method is found very useful for laying out targets and keeping station at sea in a fleet, &c., &c.

Tables of distances and angles are inserted in the general signal book.

Admiral Ryder's, or the horizon method, namely, to observe from the crosstrees or other convenient place the angle subtended between the horizon and the enemy's water line or other object, does not require any knowledge of the height of the masts of the ship or object observed, and consequently the distance from targets, rocks, breakers, &c. may be ascertained without the necessity of sending a boat to them. Admiral Ryder.

The higher the place of observation the less will any error in the angle affect the distance, but the maintop in large ships or the crosstrees in smaller vessels, would be sufficiently high for all practical purposes.

The table, p. 221, extracted from Admiral Ryder's work on this subject, should be used in the following manner:—

In every ship a table should be constructed by subtracting the correction for dip C. given in the first column of this table from the angles given along the top, putting those angles corrected to the nearest minute down under the heading "Angles observed from maintop" or crosstrees, or wherever the regular place may be; and in a second column, headed "Distances,"

Admiral Ryder.

insert the distances as given in the table. This table should be mounted on a board, and kept ready for reference.

A specimen is appended.

For a height of maintop of 95 feet, the correction is 10′ neglecting the seconds, and if the angle observed is 3° 10′, then 3° 10′ + 10′ = 3° 20′, for which the distance in the table is 544 yards.

| Angles observed from Maintop. | Distance in Yards. |
|---|---|
| ° ′ | Yards. |
| 4 50 | 372 |
| 4 20 | 399 |
| 3 50 | 452 |
| 3 40 | 472 |
| 3 30 | 494 |
| 3 20 | 517 |
| 3 10 | 544 |
| &c. | &c. |

There are four cases of the use of Admiral Ryder's method which may be useful.

Usual case.

1st case. Let the true sea horizon be visible beyond the object, and the observer be stationed in the regular position for which the board has been prepared.

If the angle is observed between the horizon and the water line of the object, and corrected for index error, if any, the distance is read off at once from the board opposite to that angle.

Exceptional place of observation.

2nd case. When the true horizon is visible beyond the enemy, but for some reason it is wished to observe from a different place than the regular one,—

Add to the observed angle the correction C. for the height of the observer, enter the table with the sum of those angles, and in line with the height will be found the distance in yards.

Land intervenes.

3rd case. In which land, the distance of which is known, intervenes between the true horizon and the observer.

Suppose the distance of the beach as ascertained from the chart to be five miles, and the angle observed between the beach and the enemy's water line be 1° 20′, and the height of the observer 140 ft.; turn the distance five miles into yards 10,000 (taking the mile as ten cables) look out for this distance in the horizontal column of distances opposite the given height 140 ft. and carry the eye up to the angle placed above it,

which in this case will be 20′, add this to the observed angle instead of the correction in column C. and look it out as in case 2. Land intervenes.

It must be remembered that when the distance of the beach in miles is greater than the square root of the height in feet, the land does not intervene between the observer and the true horizon to such an extent as to make any practical difference, and the distance is found directly by case 1.

Case 4. To find the height of another ship's mast.

Two observers are required, one aloft to take the distance of the ship by Admiral Ryder's method, and another on deck, who at the same instant takes the angle subtended by her masts. Then by entering the table in the signal book with the distance of the enemy and the angle subtended by her masts the height may be found, and afterwards for finding her distance under circumstances, perhaps, when Admiral Ryder's method could not be applied. To find height of enemy's mast.

*By Sound.*

Sound travels at the rate of about 380 yards a second; if the interval between the flash and the report of a gun in seconds be multiplied by 380 the product will be the distance in yards. Sound.

Various instruments have been proposed and tried with a view of facilitating the measurement of distances by this method.

*Range Finders or Telemeters.*

Several range finders have been designed by inventors, who profess to be able to find the distance with accuracy and rapidity from the deck, notwithstanding the motion of the ship. Range finders.

One of the most promising telemeters hitherto produced is that of General Berdan, who measures the distance by means of two telescopes at the end of a fixed base. His instruments are of various sizes. No. 7 weighs 154 lbs., has a base of about 52 in., with telescopes about 44 in. long. The time taken to measure the distance of a moving object on land is about 30 sec. Its value for naval purposes remains to be decided.

The range finders at present in use in the army are not suitable for employment at sea, and are not supplied for the naval field gun.

An efficient range finder, which can be used quickly at sea, and gives fairly accurate results, is much to be desired.

## ARRANGEMENTS FOR COMMUNICATING THE DISTANCE AND BEARING.

As long as the officer observing the distance of the enemy has to be stationed aloft, the arrangements for communication between him and the captain or the officers of the batteries will have to be specially considered.

Difficulty. It may be taken for granted that during an action it would be quite impossible to distinguish an angle or a distance hailed in the ordinary way from the masthead. A change of distance of 200 yards a minute would be a very frequent occurrence, and would probably be exceeded during an engagement, so that if the determination of the distance is to be of any value it must be communicated with the greatest possible rapidity. A telegraph working dials and bells in the top, conning tower, and batteries would apparently be the best plan. A dial with the hundreds of yards in large figures so as to be seen clearly from the upper deck, with an indicator moving along it, has been found to answer for target practice in those ships where it has been tried. It should be combined, if possible, with some means of calling attention.

Voice tubes. Voice tubes led up the masts are not so satisfactory, they require people specially stationed to attend them, and would be very liable to cause mistakes when there is noise round about them.

Dial. A dial for the purpose of enabling the officer aloft to point out the bearing of the enemy, when he might be invisible through smoke from the ship below, has been advocated by some officers.

No means available at present. Up to the present, however, no satisfactory means have been developed for measuring and rapidly communicating the distance of a quickly moving object.

## TABLES

To be used whenever the HORIZON method is adopted.

The Correction in the second column is the dip of the horizon due to the height of the observer, and must be added to the observed angle before the angle column is entered. The angle thus corrected is the angle of depression of the observed object.

In the construction of this table, owing to the very small and gradual change that takes place in the cosines of very small angles, and the necessity of using log. cosines to ten places of figures, small inaccuracies have unavoidably crept in. They never exceed the limit of probable errors of observation, and occur only when the object is at a considerable distance.

TABLE to be used when Admiral Ryder's HORIZON Method is adopted.

| Name of the part of the Ship, Masts, or Yards on which the Observer is placed. | (C) Correction to be added to Observed Angle. | Height of the Eye above the Water, in Feet. | ANGLES. | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 5° | 4° 30' | 4° | 3° 50' | 3° 40' | 3° 30' | 3° 20 | 3° 10' | 3° | 2° 55' | 2° 50 | 2° 45' | 2° 40 | 2° 35' | 2° 30 | 2° 25 | 2° 20 | 2° 15 | 2° 10' | 2° 5' | 2° 0' | 1° 58' | 1° 56 |
| | ′ ″ | | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. |
| | 4.40 | **20** | 74 | 80 | 96 | 100 | 105 | 109 | 115 | 122 | 128 | 132 | 137 | 140 | 144 | 149 | 154 | 160 | 170 | 175 | 183 | 192 | 192 | 196 | 199 |
| | 5.11 | **25** | 93 | 103 | 119 | 124 | 130 | 136 | 143 | 151 | 159 | 164 | 170 | 174 | 178 | 186 | 191 | 198 | 204 | 215 | 228 | 233 | 239 | 243 | 247 |
| | 5.43 | **30** | 111 | 125 | 142 | 148 | 155 | 162 | 171 | 180 | 189 | 196 | 203 | 208 | 213 | 220 | 227 | 236 | 243 | 255 | 267 | 274 | 285 | 290 | 295 |
| | 6.11 | **35** | 130 | 146 | 166 | 173 | 180 | 190 | 199 | 210 | 221 | 229 | 236 | 243 | 249 | 258 | 265 | 275 | 285 | 296 | 309 | 317 | 333 | 339 | 346 |
| | 6.40 | **40** | 148 | 167 | 190 | 198 | 207 | 217 | 228 | 240 | 254 | 261 | 269 | 277 | 285 | 295 | 305 | 315 | 326 | 339 | 352 | 360 | 381 | 388 | 395 |
| | 7.5 | **45** | 167 | 188 | 214 | 223 | 234 | 245 | 257 | 270 | 286 | 292 | 303 | 312 | 322 | 333 | 344 | 355 | 368 | 382 | 397 | 405 | 429 | 438 | 446 |
| | 7.30 | **50** | 185 | 210 | 238 | 248 | 260 | 272 | 286 | 301 | 318 | 324 | 337 | 347 | 358 | 370 | 382 | 395 | 409 | 425 | 441 | 452 | 477 | 486 | 495 |
| | 7.51 | **55** | 204 | 230 | 262 | 273 | 286 | 300 | 315 | 331 | 350 | 357 | 371 | 382 | 394 | 407 | 421 | 435 | 450 | 468 | 486 | 501 | 526 | 535 | 545 |
| | 8.12 | **60** | 222 | 250 | 286 | 298 | 312 | 327 | 345 | 362 | 382 | 393 | 405 | 417 | 430 | 444 | 459 | 475 | 491 | 511 | 531 | 550 | 574 | 584 | 595 |
| | 8.32 | **65** | 240 | 272 | 310 | 323 | 339 | 354 | 373 | 392 | 415 | 426 | 439 | 452 | 466 | 481 | 497 | 515 | 532 | 553 | 575 | 596 | 622 | 634 | 646 |
| | 8.59 | **70** | 259 | 293 | 334 | 348 | 365 | 382 | 402 | 423 | 447 | 459 | 472 | 486 | 502 | 518 | 535 | 554 | 573 | 595 | 618 | 644 | 770 | 683 | 695 |
| | 9.10 | **75** | 287 | 314 | 357 | 373 | 391 | 408 | 429 | 452 | 478 | 491 | 505 | 520 | 537 | 554 | 572 | 592 | 613 | 637 | 661 | 689 | 716 | 729 | 743 |
| | 9.28 | **80** | 305 | 335 | 380 | 397 | 415 | 434 | 457 | 481 | 508 | 522 | 537 | 554 | 571 | 590 | 609 | 630 | 652 | 678 | 703 | 733 | 762 | 777 | 791 |
| | 9.45 | **85** | 333 | 356 | 404 | 422 | 441 | 461 | 486 | 511 | 540 | 555 | 571 | 580 | 607 | 627 | 648 | 670 | 693 | 721 | 748 | 779 | 810 | 825 | 841 |
| | 10.3 | **90** | 352 | 377 | 428 | 447 | 467 | 489 | 515 | 542 | 572 | 588 | 605 | 624 | 643 | 664 | 686 | 710 | 735 | 763 | 793 | 825 | 858 | 874 | 890 |
| | 10.19 | **95** | 372 | 399 | 452 | 472 | 494 | 517 | 544 | 572 | 604 | 621 | 639 | 659 | 679 | 702 | 725 | 750 | 776 | 806 | 838 | 872 | 907 | 923 | 940 |
| | 10 35 | **100** | 392 | 420 | 476 | 497 | 520 | 545 | 574 | 603 | 636 | 654 | 673 | 694 | 715 | 739 | 763 | 790 | 817 | 849 | 882 | 920 | 955 | 972 | 990 |
| | 10.51 | **105** | 411 | 440 | 500 | 522 | 546 | 572 | 603 | 634 | 669 | 687 | 708 | 729 | 751 | 776 | 802 | 830 | 850 | 892 | 927 | 965 | 1001 | 1018 | 1040 |
| | 11.7 | **110** | 429 | 460 | 524 | 547 | 572 | 600 | 632 | 664 | 701 | 721 | 742 | 764 | 786 | 813 | 840 | 870 | 900 | 935 | 971 | 1009 | 1047 | 1065 | 1000 |
| | 11.22 | **115** | 449 | 482 | 548 | 572 | 599 | 627 | 661 | 695 | 733 | 754 | 776 | 800 | 823 | 851 | 879 | 910 | 941 | 978 | 1016 | 1050 | 1097 | 1118 | 1140 |
| | 11.38 | **120** | 466 | 503 | 572 | 597 | 625 | 655 | 690 | 725 | 765 | 787 | 810 | 835 | 859 | 888 | 917 | 950 | 982 | 1021 | 1060 | 1097 | 1145 | 1168 | 1190 |
| | 11.52 | **125** | 485 | 524 | 595 | 621 | 650 | 681 | 717 | 754 | 796 | 819 | 843 | 868 | 894 | 924 | 954 | 988 | 1022 | 1062 | 1105 | 1142 | 1193 | 1213 | 1238 |
| | 12.6 | **130** | 503 | 545 | 618 | 645 | 675 | 707 | 745 | 783 | 826 | 850 | 875 | 901 | 928 | 960 | 991 | 1026 | 1061 | 1103 | 1147 | 1190 | 1239 | 1262 | 1285 |
| | 12.19 | **135** | 522 | 567 | 642 | 670 | 701 | 734 | 774 | 814 | 858 | 884 | 909 | 936 | 984 | 997 | 1030 | 1066 | 1102 | 1146 | 1190 | 1239 | 1288 | 1311 | 1335 |
| | 12.33 | **140** | 540 | 588 | 666 | 695 | 727 | 762 | 803 | 844 | 890 | 917 | 943 | 971 | 1000 | 1034 | 1068 | 1105 | 1143 | 1188 | 1234 | 1284 | 1336 | 1360 | 1385 |
| | 12.46 | **145** | 559 | 609 | 690 | 721 | 754 | 789 | 831 | 875 | 922 | 950 | 977 | 1006 | 1036 | 1071 | 1107 | 1145 | 1185 | 1231 | 1278 | 1330 | 1384 | 1409 | 1435 |
| | 13.0 | **150** | 577 | 630 | 714 | 746 | 780 | 816 | 860 | 905 | 954 | 983 | 1011 | 1041 | 1072 | 1108 | 1145 | 1185 | 1226 | 1274 | 1322 | 1377 | 1432 | 1458 | 1485 |
| Alteration in Distance for 1 foot in height - - - | | | yds. 3 | yds. 4 | yds. 5 | yds. 5 | yds. 5 | yds. 5 | yds. 6 | yds. 6 | yds. 6 | yds. 6 | yds. 7 | yds. 7 | yds. 7 | yds. 7 | yds. 8 | yds. 8 | yds. 8 | yds. 8 | yds. 9 | yds. 9 | yds. 9 | yds. 9 | yds. 10 |

TABLE to be used when Admiral Ryder's HORIZON Method is adopted.

| Name of the part of the Ship, Masts, or Yards, on which the Observer is placed. | (C) Correction to be added to Observed Angle. | Height of the Eye above the Water, in Feet. | ANGLES. | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1° 54′ | 1° 52′ | 1° 50′ | 1° 48′ | 1° 46′ | 1° 44 | 1° 42′ | 1° 40′ | 1° 38 | 1° 36′ | 1° 34′ | 1° 32′ | 1° 30′ | 1° 28 | 1° 26′ | 1° 24′ | 1° 22 | 1° 20′ | 1° 18 | 1° 16 | 1° 14 | 1° 12′ | 1° 10′ |
| | ′ ″ | | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. |
| | 4.40 | **20** | 203 | 207 | 210 | 214 | 218 | 222 | 228 | 232 | 238 | 242 | 247 | 253 | 259 | 264 | 270 | 277 | 284 | 291 | 298 | 306 | 315 | 323 | 333 |
| | 5.11 | **25** | 252 | 258 | 260 | 265 | 270 | 275 | 282 | 287 | 297 | 300 | 306 | 313 | 320 | 327 | 335 | 345 | 351 | 360 | 369 | 379 | 391 | 400 | 412 |
| | 5.43 | **30** | 300 | 307 | 301 | 316 | 322 | 328 | 336 | 342 | 353 | 359 | 366 | 375 | 383 | 390 | 410 | 410 | 420 | 431 | 442 | 454 | 467 | 478 | 492 |
| | 6.11 | **35** | 351 | 357 | 363 | 370 | 377 | 384 | 392 | 400 | 409 | 419 | 427 | 437 | 446 | 456 | 466 | 478 | 490 | 502 | 515 | 529 | 544 | 557 | 575 |
| | 6.40 | **40** | 402 | 408 | 416 | 424 | 432 | 440 | 449 | 458 | 468 | 479 | 489 | 500 | 511 | 522 | 533 | 547 | 561 | 575 | 590 | 605 | 622 | 639 | 659 |
| | 7.5 | **45** | 453 | 461 | 469 | 478 | 487 | 496 | 506 | 516 | 528 | 540 | 551 | 563 | 576 | 588 | 601 | 616 | 632 | 648 | 665 | 682 | 701 | 720 | 740 |
| | 7.30 | **50** | 503 | 512 | 522 | 532 | 542 | 552 | 563 | 574 | 587 | 600 | 613 | 626 | 641 | 654 | 669 | 685 | 703 | 721 | 739 | 758 | 780 | 801 | 823 |
| | 7.51 | **55** | 554 | 564 | 575 | 586 | 597 | 608 | 620 | 632 | 646 | 661 | 675 | 689 | 705 | 720 | 735 | 754 | 774 | 794 | 814 | 834 | 858 | 882 | 907 |
| | 8.12 | **60** | 605 | 616 | 627 | 639 | 651 | 663 | 676 | 690 | 705 | 721 | 736 | 752 | 769 | 786 | 802 | 823 | 844 | 866 | 888 | 910 | 936 | 960 | 992 |
| | 8.32 | **65** | 657 | 668 | 680 | 693 | 706 | 719 | 733 | 748 | 765 | 782 | 799 | 816 | 834 | 852 | 871 | 893 | 916 | 939 | 963 | 987 | 1017 | 1042 | 1077 |
| | 8.52 | **70** | 708 | 720 | 733 | 747 | 761 | 775 | 790 | 806 | 824 | 842 | 862 | 879 | 899 | 918 | 939 | 962 | 985 | 1011 | 1037 | 1062 | 1094 | 1121 | 1159 |
| | 9.10 | **75** | 756 | 769 | 785 | 799 | 812 | 828 | 844 | 865 | 881 | 900 | 921 | 939 | 961 | 981 | 1005 | 1028 | 1054 | 1080 | 1108 | 1136 | 1170 | 1200 | 1240 |
| | 9.28 | **80** | 805 | 818 | 835 | 850 | 865 | 881 | 898 | 919 | 937 | 958 | 979 | 999 | 1022 | 1044 | 1070 | 1094 | 1123 | 1149 | 1179 | 1210 | 1246 | 1278 | 1323 |
| | 9.45 | **85** | 854 | 869 | 887 | 904 | 920 | 937 | 955 | 978 | 996 | 1019 | 1042 | 1062 | 1086 | 1110 | 1137 | 1163 | 1192 | 1222 | 1254 | 1286 | 1322 | 1359 | 1406 |
| | 10.3 | **90** | 905 | 920 | 939 | 957 | 975 | 993 | 1012 | 1032 | 1055 | 1079 | 1102 | 1125 | 1150 | 1176 | 1204 | 1232 | 1263 | 1295 | 1329 | 1363 | 1401 | 1439 | 1487 |
| | 10.19 | **95** | 956 | 973 | 992 | 1011 | 1030 | 1049 | 1069 | 1090 | 1115 | 1140 | 1164 | 1189 | 1216 | 1242 | 1272 | 1302 | 1335 | 1368 | 1404 | 1440 | 1480 | 1520 | 1568 |
| | 10.35 | **100** | 1007 | 1025 | 1045 | 1065 | 1085 | 1104 | 1126 | 1148 | 1174 | 1200 | 1226 | 1252 | 1281 | 1308 | 1339 | 1371 | 1406 | 1441 | 1479 | 1517 | 1559 | 1601 | 1651 |
| | 10.51 | **105** | 1058 | 1077 | 1099 | 1118 | 1119 | 1160 | 1182 | 1204 | 1232 | 1261 | 1288 | 1315 | 1345 | 1374 | 1407 | 1440 | 1477 | 1514 | 1553 | 1593 | 1637 | 1682 | 1735 |
| | 11.7 | **110** | 1109 | 1129 | 1150 | 1172 | 1192 | 1216 | 1238 | 1259 | 1290 | 1321 | 1349 | 1378 | 1408 | 1439 | 1474 | 1509 | 1547 | 1586 | 1627 | 1668 | 1715 | 1763 | 1818 |
| | 11.22 | **115** | 1160 | 1181 | 1203 | 1226 | 1248 | 1272 | 1296 | 1321 | 1351 | 1382 | 1411 | 1442 | 1473 | 1506 | 1542 | 1578 | 1618 | 1659 | 1702 | 1745 | 1794 | 1844 | 1902 |
| | 11.38 | **120** | 1211 | 1232 | 1255 | 1279 | 1303 | 1327 | 1352 | 1380 | 1411 | 1442 | 1473 | 1505 | 1538 | 1572 | 1609 | 1647 | 1689 | 1732 | 1777 | 1820 | 1871 | 1925 | 1983 |
| | 11.52 | **125** | 1258 | 1278 | 1307 | 1332 | 1356 | 1380 | 1407 | 1435 | 1468 | 1500 | 1532 | 1565 | 1600 | 1635 | 1675 | 1713 | 1757 | 1802 | 1849 | 1895 | 1948 | 2002 | 2064 |
| | 12.6 | **130** | 1308 | 1329 | 1359 | 1384 | 1409 | 1433 | 1461 | 1490 | 1524 | 1558 | 1591 | 1625 | 1663 | 1698 | 1740 | 1779 | 1825 | 1871 | 1920 | 1970 | 2025 | 2079 | 2145 |
| | 12.19 | **135** | 1359 | 1380 | 1411 | 1437 | 1464 | 1489 | 1518 | 1548 | 1583 | 1619 | 1653 | 1688 | 1726 | 1764 | 1807 | 1848 | 1896 | 1944 | 1994 | 2045 | 2102 | 2160 | 2227 |
| | 12.33 | **140** | 1410 | 1435 | 1462 | 1490 | 1518 | 1545 | 1575 | 1606 | 1642 | 1679 | 1715 | 1751 | 1791 | 1830 | 1873 | 1917 | 1967 | 2016 | 2068 | 2121 | 2181 | 2240 | 2310 |
| | 12.46 | **145** | 1460 | 1487 | 1515 | 1544 | 1573 | 1600 | 1633 | 1664 | 1702 | 1740 | 1777 | 1815 | 1856 | 1896 | 1941 | 1986 | 2038 | 2090 | 2142 | 2198 | 2260 | 2321 | 2394 |
| | 13.0 | **150** | 1511 | 1538 | 1568 | 1598 | 1628 | 1657 | 1690 | 1723 | 1761 | 1800 | 1839 | 1878 | 1920 | 1962 | 2008 | 2055 | 2108 | 2162 | 2218 | 2274 | 2338 | 2402 | 2477 |
| Alteration in Distance for 1 foot in height - - - | | | yds. 10 | yds. 10 | yds. 10 | yds. 10 | yds. 11 | yds. 11 | yds. 11 | yds. 11 | yds. 12 | yds. 12 | yds. 12 | yds. 12 | yds. 13 | yds. 13 | yds. 13 | yds. 13 | yds. 14 | yds. 14 | yds. 14 | yds. 15 | yds. 15 | yds. 16 | yds. 16 |

TABLE to be used when Admiral Ryder's HORIZON Method is adopted.

| Name of the part of the Ship, Masts, or Yards, on which the Observer is placed. | (C) Correction to be added to Observed Angle. | Height of the Eye above the Water, in Feet. | ANGLES. 1° 8′ | 1° 6 | 1° 4′ | 1° 2′ | 1° 0′ | 0° 59′ | 0° 58′ | 0° 57′ | 0° 56′ | 0° 55′ | 0° 54′ | 0° 53′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ′ ″ | | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. |
| | 4.40 | **20** | 343 | 354 | 365 | 378 | 391 | 398 | 405 | 412 | 420 | 427 | 435 | 444 |
| | 5.11 | **25** | 425 | 429 | 454 | 468 | 486 | 493 | 502 | 511 | 520 | 529 | 539 | 550 |
| | 5.43 | **30** | 509 | 521 | 543 | 560 | 580 | 590 | 599 | 611 | 622 | 632 | 645 | 658 |
| | 6.11 | **35** | 593 | 612 | 632 | 653 | 676 | 687 | 699 | 712 | 725 | 738 | 751 | 767 |
| | 6.40 | **40** | 679 | 701 | 723 | 748 | 773 | 786 | 800 | 815 | 830 | 845 | 860 | 878 |
| | 7.5 | **45** | 765 | 790 | 815 | 843 | 871 | 886 | 902 | 918 | 935 | 952 | 969 | 989 |
| | 7.30 | **50** | 851 | 878 | 906 | 938 | 968 | 985 | 1003 | 1021 | 1040 | 1058 | 1077 | 1100 |
| | 7.51 | **55** | 937 | 967 | 997 | 1035 | 1066 | 1084 | 1104 | 1124 | 1145 | 1165 | 1186 | 1211 |
| | 8.12 | **60** | 1022 | 1055 | 1088 | 1131 | 1164 | 1182 | 1205 | 1227 | 1250 | 1272 | 1295 | 1321 |
| | 8.32 | **65** | 1108 | 1144 | 1180 | 1223 | 1262 | 1283 | 1306 | 1330 | 1355 | 1379 | 1404 | 1433 |
| | 8.52 | **70** | 1192 | 1230 | 1271 | 1315 | 1359 | 1380 | 1405 | 1431 | 1460 | 1484 | 1510 | 1542 |
| | 9.10 | **75** | 1276 | 1317 | 1359 | 1406 | 1453 | 1475 | 1504 | 1532 | 1560 | 1588 | 1616 | 1650 |
| | 9.28 | **80** | 1359 | 1404 | 1446 | 1496 | 1547 | 1572 | 1598 | 1632 | 1660 | 1692 | 1722 | 1758 |
| | 9.45 | **85** | 1443 | 1492 | 1538 | 1590 | 1644 | 1670 | 1701 | 1733 | 1765 | 1797 | 1829 | 1867 |
| | 10.8 | **90** | 1529 | 1579 | 1629 | 1684 | 1741 | 1772 | 1802 | 1836 | 1870 | 1903 | 1937 | 1978 |
| | 10.19 | **95** | 1615 | 1669 | 1723 | 1780 | 1839 | 1872 | 1903 | 1939 | 1975 | 2010 | 2046 | 2089 |
| | 10.35 | **100** | 1701 | 1759 | 1817 | 1875 | 1936 | 1971 | 2005 | 2042 | 2080 | 2117 | 2155 | 2200 |
| | 10.51 | **105** | 1787 | 1846 | 1906 | 1970 | 2034 | 2070 | 2106 | 2145 | 2185 | 2224 | 2264 | 2311 |
| | 11.7 | **110** | 1872 | 1933 | 1994 | 2063 | 2132 | 2169 | 2206 | 2248 | 2290 | 2331 | 2372 | 2422 |
| | 11.22 | **115** | 1959 | 2022 | 2086 | 2158 | 2229 | 2269 | 2308 | 2352 | 2395 | 2438 | 2481 | 2534 |
| | 11.38 | **120** | 2043 | 2109 | 2177 | 2252 | 2327 | 2368 | 2408 | 2453 | 2498 | 2543 | 2590 | 2643 |
| | 11.52 | **125** | 2127 | 2196 | 2265 | 2343 | 2421 | 2464 | 2507 | 2553 | 2600 | 2647 | 2696 | 2751 |
| | 12.6 | **130** | 2210 | 2282 | 2354 | 2433 | 2514 | 2559 | 2606 | 2653 | 2702 | 2750 | 2802 | 2859 |
| | 12.19 | **135** | 2295 | 2369 | 2444 | 2528 | 2612 | 2659 | 2705 | 2754 | 2805 | 2855 | 2909 | 2968 |
| | 12.33 | **140** | 2380 | 2457 | 2535 | 2622 | 2709 | 2757 | 2805 | 2857 | 2911 | 2962 | 3015 | 3078 |
| | 12.46 | **145** | 2466 | 2547 | 2626 | 2717 | 2807 | 2857 | 2906 | 2960 | 3015 | 3069 | 3124 | 3189 |
| | 13.0 | **150** | 2552 | 2636 | 2717 | 2811 | 2905 | 2956 | 3007 | 3062 | 3120 | 3176 | 3232 | 3300 |
| Alteration in Distance for 1 foot in height - - - | | | yds. 17 | yds. 17 | yds. 18 | yds. 19 | yds. 19 | yds. 20 | yds. 20 | yds. 21 | yds. 21 | yds. 21 | yds. 21 | yds. 22 |

| Name of the part of the Ship, Masts, or Yards, on which the Observer is placed. | (C) Correction to be added to Observed Angle. | Height of the Eye above the Water, in Feet. | 0° 52′ | 0° 51′ | 0° 50′ | 0° 49′ | 0° 48′ | 0° 47′ | 0° 46′ | 0° 45′ | 0° 44′ | 0° 43′ | 0° 42′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ′ ″ | | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. |
| | 4.40 | **20** | 453 | 463 | 473 | 488 | 493 | 504 | 516 | 528 | 540 | 554 | 568 |
| | 5.11 | **25** | 567 | 574 | 586 | 598 | 610 | 624 | 639 | 654 | 669 | 687 | 704 |
| | 5.43 | **30** | 675 | 687 | 701 | 715 | 727 | 746 | 765 | 780 | 801 | 819 | 842 |
| | 6.11 | **35** | 783 | 800 | 817 | 833 | 854 | 871 | 891 | 912 | 933 | 955 | 981 |
| | 6.40 | **40** | 896 | 916 | 935 | 958 | 974 | 997 | 1020 | 1044 | 1068 | 1095 | 1122 |
| | 7.5 | **45** | 1009 | 1032 | 1054 | 1076 | 1098 | 1123 | 1149 | 1176 | 1203 | 1231 | 1260 |
| | 7.30 | **50** | 1123 | 1148 | 1172 | 1197 | 1221 | 1249 | 1278 | 1308 | 1338 | 1367 | 1405 |
| | 7.51 | **55** | 1237 | 1264 | 1290 | 1317 | 1344 | 1375 | 1406 | 1440 | 1473 | 1508 | 1550 |
| | 8.12 | **60** | 1350 | 1379 | 1408 | 1437 | 1466 | 1500 | 1535 | 1570 | 1608 | 1649 | 1690 |
| | 8.32 | **65** | 1463 | 1495 | 1528 | 1558 | 1589 | 1626 | 1664 | 1703 | 1743 | 1789 | 1833 |
| | 8.52 | **70** | 1574 | 1610 | 1652 | 1676 | 1712 | 1752 | 1790 | 1833 | 1879 | 1927 | 1972 |
| | 9.10 | **75** | 1684 | 1725 | 1759 | 1794 | 1832 | 1874 | 1916 | 1962 | 2009 | 2059 | 2111 |
| | 9.28 | **80** | 1796 | 1840 | 1874 | 1911 | 1951 | 1995 | 2041 | 2090 | 2136 | 2191 | 2249 |
| | 9.45 | **85** | 1906 | 1955 | 1989 | 2030 | 2072 | 2120 | 2169 | 2220 | 2275 | 2329 | 2388 |
| | 10.8 | **90** | 2019 | 2070 | 2107 | 2150 | 2195 | 2245 | 2298 | 2352 | 2408 | 2467 | 2529 |
| | 10.19 | **95** | 2133 | 2185 | 2226 | 2272 | 2319 | 2372 | 2427 | 2484 | 2544 | 2606 | 2672 |
| | 10.35 | **100** | 2246 | 2298 | 2344 | 2394 | 2442 | 2499 | 2554 | 2616 | 2677 | 2745 | 2814 |
| | 10.51 | **105** | 2360 | 2412 | 2462 | 2514 | 2565 | 2625 | 2673 | 2748 | 2811 | 2884 | 2956 |
| | 11.7 | **110** | 2473 | 2528 | 2580 | 2633 | 2687 | 2750 | 2814 | 2880 | 2946 | 3022 | 3098 |
| | 11.22 | **115** | 2587 | 2644 | 2699 | 2755 | 2811 | 2877 | 2943 | 3012 | 3086 | 3161 | 3230 |
| | 11.38 | **120** | 2698 | 2757 | 2817 | 2876 | 2932 | 3001 | 3070 | 3142 | 3217 | 3296 | 3374 |
| | 11.52 | **125** | 2808 | 2870 | 2933 | 2994 | 3053 | 3124 | 3195 | 3270 | 3346 | 3431 | 3518 |
| | 12.6 | **130** | 2921 | 2952 | 3045 | 3111 | 3173 | 3246 | 3321 | 3399 | 3479 | 3568 | 3656 |
| | 12.19 | **135** | 3034 | 3094 | 3161 | 3229 | 3293 | 3370 | 3447 | 3529 | 3611 | 3705 | 3795 |
| | 12.33 | **140** | 3145 | 3208 | 3229 | 3347 | 3415 | 3495 | 3576 | 3661 | 3747 | 3842 | 3937 |
| | 12.46 | **145** | 3257 | 3325 | 3309 | 3468 | 3539 | 3621 | 3705 | 3792 | 3881 | 3980 | 4079 |
| | 13.0 | **150** | 3369 | 3442 | 3516 | 3589 | 3662 | 3747 | 3833 | 3923 | 4015 | 4117 | 4221 |
| Alteration in Distance for 1 foot in height - - - | | | yds. 22 | yds. 23 | yds. 23 | yds. 24 | yds. 24 | yds. 25 | yds. 25 | yds. 26 | yds. 26 | yds. 27 | yds. 27 |

TABLE to be used when Admiral Ryder's HORIZON Method is adopted.

| Name of the part of the Ship, Masts, or Yards, on which the Observer is placed. | (C) Correction to be added to Observed Angle. | Height of the Eye above the Water, in Feet. | ANGLES. 0° 41′ | 0° 40′ | 0° 39′ | 0° 38′ | 0° 37′ | 0° 36 | 0° 35′ | 0° 34 | 0° 33′ | 0° 32′ | 0° 31′ | 0° 30′ | 0° 29′ | 0° 28 | 0° 27 | 0° 26 | 0° 25′ | 0° 24′ | 0° 23′ | 0° 22′ | 0° 21′ | 0° 20 | 0° 19′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ′ ″ | | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. | yds. |
| | 4.40 | 20 | 583 | 598 | 614 | 631 | 651 | 672 | 694 | 716 | 741 | 767 | 796 | 825 | 862 | 895 | 933 | 973 | 1035 | 1080 | 1152 | 1227 | 1311 | 1413 | 1536 |
| | 5.11 | 25 | 722 | 740 | 761 | 782 | 807 | 833 | 860 | 887 | 918 | 950 | 986 | 1022 | 1068 | 1108 | 1155 | 1205 | 1282 | 1350 | 1428 | 1519 | 1624 | 1750 | 1902 |
| | 5.48 | 30 | 864 | 886 | 910 | 935 | 964 | 997 | 1032 | 1062 | 1099 | 1137 | 1185 | 1226 | 1273 | 1325 | 1383 | 1442 | 1534 | 1616 | 1710 | 1818 | 1944 | 2094 | 2277 |
| | 6.11 | 35 | 1007 | 1033 | 1060 | 1088 | 1124 | 1161 | 1204 | 1237 | 1281 | 1324 | 1384 | 1430 | 1484 | 1544 | 1611 | 1681 | 1787 | 1882 | 1992 | 2118 | 2264 | 2439 | 2652 |
| | 6 40 | 40 | 1152 | 1183 | 1213 | 1243 | 1286 | 1329 | 1372 | 1416 | 1466 | 1516 | 1587 | 1634 | 1698 | 1767 | 1844 | 1924 | 2045 | 2155 | 2281 | 2424 | 2592 | 2792 | 3036 |
| | 7.5 | 45 | 1296 | 1333 | 1363 | 1404 | 1444 | 1498 | 1546 | 1595 | 1651 | 1708 | 1789 | 1837 | 1914 | 1991 | 2078 | 2168 | 2304 | 2428 | 2570 | 2731 | 2920 | 3146 | 3421 |
| | 7.30 | 50 | 1440 | 1483 | 1517 | 1564 | 1602 | 1666 | 1720 | 1734 | 1826 | 1899 | 1979 | 2043 | 2129 | 2215 | 2311 | 2411 | 2563 | 2701 | 2858 | 3038 | 3248 | 3499 | 3805 |
| | 7.51 | 55 | 1588 | 1632 | 1671 | 1722 | 1771 | 1834 | 1894 | 1953 | 2022 | 2090 | 2170 | 2250 | 2344 | 2439 | 2545 | 2654 | 2822 | 2974 | 3147 | 3345 | 3576 | 3853 | 4189 |
| | 8.12 | 60 | 1736 | 1782 | 1830 | 1879 | 1940 | 2002 | 2067 | 2132 | 2207 | 2282 | 2369 | 2456 | 2559 | 2662 | 2778 | 2897 | 3081 | 3246 | 3435 | 3652 | 3904 | 4206 | 4573 |
| | 8.32 | 65 | 1882 | 1932 | 1984 | 2037 | 2106 | 2170 | 2241 | 2311 | 2392 | 2474 | 2569 | 2662 | 2774 | 2886 | 3012 | 3141 | 3340 | 3519 | 3724 | 3959 | 4232 | 4559 | 4957 |
| | 8.52 | 70 | 2026 | 2082 | 2135 | 2195 | 2266 | 2335 | 2414 | 2490 | 2577 | 2661 | 2766 | 2868 | 2988 | 3104 | 3240 | 3380 | 3593 | 3786 | 4005 | 4261 | 4568 | 4904 | 5332 |
| | 9.10 | 75 | 2167 | 2229 | 2285 | 2351 | 2425 | 2499 | 2587 | 2667 | 2766 | 2848 | 2961 | 3073 | 3198 | 3322 | 3467 | 3517 | 3843 | 4052 | 4287 | 4563 | 4873 | 5249 | 5707 |
| | 9.28 | 80 | 2308 | 2367 | 2435 | 2508 | 2582 | 2663 | 2757 | 2842 | 2952 | 3035 | 3157 | 3276 | 3408 | 3539 | 3694 | 3854 | 4096 | 4318 | 4567 | 4856 | 5193 | 5595 | 6083 |
| | 9.45 | 85 | 2452 | 2517 | 2586 | 2664 | 2741 | 2827 | 2926 | 3021 | 3138 | 3222 | 3354 | 3478 | 3618 | 3759 | 3923 | 4093 | 4350 | 4584 | 4853 | 5157 | 5513 | 5939 | 6458 |
| | 10.3 | 90 | 2598 | 2667 | 2739 | 2819 | 2903 | 2995 | 3092 | 3200 | 3320 | 3413 | 3553 | 3674 | 3830 | 3983 | 4156 | 4336 | 4609 | 4857 | 5149 | 5463 | 5841 | 6292 | 6842 |
| | 10.19 | 95 | 2744 | 2817 | 2889 | 2975 | 3066 | 3163 | 3265 | 3377 | 3502 | 3606 | 3748 | 3881 | 4043 | 4207 | 4390 | 4580 | 4868 | 5130 | 5129 | 5771 | 6173 | 6646 | 7229 |
| | 10.35 | 100 | 2890 | 2967 | 3042 | 3138 | 3229 | 3330 | 3436 | 3541 | 3683 | 3798 | 3942 | 4087 | 4258 | 4430 | 4623 | 4823 | 5127 | 5103 | 5717 | 6077 | 6505 | 6999 | 7616 |
| | 10.51 | 105 | 3035 | 3114 | 3196 | 3291 | 3392 | 3499 | 3612 | 3725 | 3864 | 3990 | 4141 | 4293 | 4474 | 4654 | 4857 | 5066 | 5386 | 5671 | 6006 | 6384 | 6834 | 7352 | 7997 |
| | 11.7 | 110 | 3179 | 3261 | 3352 | 3444 | 3556 | 3667 | 3787 | 3907 | 4044 | 4181 | 4340 | 4499 | 4688 | 4877 | 5090 | 5309 | 5644 | 5948 | 6294 | 6690 | 7162 | 7705 | 8378 |
| | 11.22 | 115 | 3321 | 3413 | 3500 | 3602 | 3719 | 3837 | 3955 | 4086 | 4230 | 4373 | 4539 | 4706 | 4903 | 5101 | 5324 | 5553 | 5903 | 6222 | 6583 | 6998 | 7486 | 8059 | 8763 |
| | 11.38 | 120 | 3464 | 3565 | 3650 | 3757 | 3880 | 4001 | 4125 | 4261 | 4411 | 4563 | 4734 | 4909 | 5114 | 5325 | 5557 | 5793 | 6157 | 6490 | 6865 | 7300 | 7804 | 8404 | 9139 |
| | 11.52 | 125 | 3607 | 3713 | 3800 | 3911 | 4038 | 4165 | 4294 | 4436 | 4592 | 4753 | 4929 | 5110 | 5324 | 5538 | 5780 | 6033 | 6410 | 6755 | 7147 | 7595 | 8122 | 8749 | 9513 |
| | 12.6 | 130 | 3751 | 3856 | 3955 | 4065 | 4196 | 4329 | 4468 | 4610 | 4772 | 4937 | 5123 | 5311 | 5629 | 5751 | 6010 | 6267 | 6663 | 7020 | 7427 | 7895 | 8442 | 9093 | 9888 |
| | 12.19 | 135 | 3893 | 4000 | 4109 | 4219 | 4356 | 4493 | 4639 | 4785 | 4953 | 5122 | 5317 | 5513 | 5743 | 5975 | 6239 | 6505 | 6915 | 7287 | 7711 | 8196 | 8762 | 9438 | 10263 |
| | 12.33 | 140 | 4043 | 4149 | 4262 | 4376 | 4518 | 4661 | 4812 | 4964 | 5118 | 5313 | 5515 | 5717 | 5957 | 6198 | 6468 | 6748 | 7172 | 7559 | 7999 | 8502 | 9090 | 9791 | 10647 |
| | 12.46 | 145 | 4189 | 4299 | 4416 | 4534 | 4682 | 4830 | 4986 | 5143 | 5320 | 5505 | 5714 | 5924 | 6173 | 6422 | 6702 | 6991 | 7431 | 7832 | 8287 | 8809 | 9418 | 10145 | 11031 |
| | 13.0 | 150 | 4334 | 4448 | 4570 | 4693 | 4845 | 4998 | 5160 | 5323 | 5500 | 5696 | 5913 | 6131 | 6388 | 6645 | 6935 | 7234 | 7691 | 8104 | 8575 | 9116 | 9746 | 10498 | 11415 |
| Alteration in Distance for 1 foot in height - - - | | | yds. 28 | yds. 29 | yds. 30 | yds. 31 | yds. 32 | yds. 33 | yds. 34 | yds. 35 | yds. 36 | yds. 37 | yds. 39 | yds. 41 | yds. 42 | yds. 44 | yds. 46 | yds. 47 | yds. 50 | yds. 53 | yds. 56 | yds. 61 | yds. 66 | yds. 71 | yds. 76 |

# CHAPTER XI.

## SYSTEMS OF FIRING.

### General Remarks.

The guns may be fired either separately, called Independent Firing, or several together by order or electricity, called Broadside Firing. Definition.

Simultaneous firing is a special description of independent firing used in turret ships; the term Independent Firing being there restricted to the case in which the two guns in each turret work independently of each other.

The relative advantages of these different systems of firing are at present very much matters of opinion, and must remain so until they have been verified by experiment. They can only be finally decided by actual war, but great caution must be exercised against drawing hasty conclusions from an isolated action. They vary under many circumstances; such as, whether the action is between fleets or single ships, or between ships and forts; also with the speed and steadiness of the ship, the distance, and movement, if any, of the enemy; whether the smoke clears away or hangs about the ship, and many minor points. Relative advantages undecided.

The following arguments are given, not as laying down any rule as to what description of firing would be used under any particular circumstances, but as affording matter for consideration before Officers are called on to assume the responsibility of deciding how they would fight their ships. Arguments suggestive.

The fundamental idea is to ascertain the system which gives the greatest number of hits in a given time. When the distance and direction are constant, the gun on a fixed platform, and errors of pointing, wind, &c. eliminated, the sizes of the targets, which will be hit by 50 per cent. of the shot fired, have been deduced from experiments with various guns. So long as smoke does not interfere, the number of hits on these targets will increase with the number of guns, but when it does not clear away, as is often the case, there System dependent upon number of guns and distance.

must be some number of guns with which under these circumstances Independent Firing becomes so slow that at short ranges Broadsides give a greater number of hits, because, although not so accurate, a greater number of shot can be fired with a fair amount of precision; so that, under these conditions, the description of firing depends upon the number of guns and upon the distance of the object.

No experiments from rolling platform.

Hardly any experiments have as yet been carried out to ascertain approximately the probability of hitting a given object with the present rifled guns, when average shots are firing at known distances from a rolling or heaving platform.

Steady platform in motion.

When the guns are mounted on a steady platform, moving at high speed, and the distance and bearing remain nearly constant, as when ships are steering on parallel courses, the description of firing will depend, as before explained, on the number of guns and on the distance of the object.

Effect of changes in distance.

But when the distance is constantly changing, the number of hits from a single gun depends primarily on the accuracy and rapidity with which the distance can be ascertained, as well as on the rate at which it changes. The facility with which the gun can be elevated and the sight adjusted also affects the number of hits. As there must be an appreciable interval between the determination of the distance and the firing of the gun, a source of error is introduced which can only be eliminated by laying the gun beforehand and firing when the distance comes on. Hence a great reduction in the probable number of hits in any given time from a single gun when the distance changes as compared with that when the range does not alter.

Under these conditions the distance up to which firing from a single gun can be advantageously carried on depends upon the relative magnitudes of the dangerous spaces, p. 130, and of the change in the distance in a given small interval of time.

An inspection of table, p. 183, and of the curves of dangerous space, p. 131, will show that this distance is comparatively short. It will be observed that with the guns now afloat, at ranges of about 1,500 yards, the dangerous space becomes so small that the chance of hitting is much reduced when the distance is changing rapidly, while on the other hand at ranges of 800 yards and under, any change in the distance becomes of no practical importance. The only element which can check the rapidity of independent firing from a number of guns, at these short ranges, when the bearing is nearly constant, is the smoke.

Changes of bearing.

If the bearing changes rapidly the number of hits will greatly depend on the facility with which the guns can be

trained. This rapid change of bearing is more likely to occur at short ranges than at long ones, and may make the opportunity for firing so short (*vide* table, p. 187) that with a number of guns only a portion can be fired.

Summary.

Hence it may be inferred that when the distance and bearing are constantly changing, the system of firing most suitable depends upon—

1. The number of guns.
2. Whether the Captains of the guns have a sufficient view.
3. The distance at which it is necessary to fire.
4. The rapidity with which the bearing and distance alters, and the means of communicating these changes.

Use of Broadside or Independent Firing.

With a large number of guns, of which the Nos. 1 have not a wide view, Broadside Firing would as a rule be used within certain limits of range beyond which Independent Firing would probably give the best results. It does not seem likely that either system of firing would give more than a small proportion of hits. The Independent Firing would fail, because the difficulty of communicating the distance would make the fire inaccurate, and the smoke might make it slow. The Broadside Firing would be unsuccessful, because the guns are to a certain extent fixed in training and elevation, so that many chances must be lost owing to the direction not coming on, or to the elevation being thrown out by the helm, wind, &c.

Independent Firing used with advantage.

If the number of guns is small and the Nos. 1 can see, Independent Firing can be carried out with advantage at all ranges within which an engagement would be carried on, for at the longer ranges the difficulty of communicating the distance will be reduced, and the smoke from one gun will not interfere with the fire from the next; at the shorter ranges the disadvantage of the guns being fixed in direction will be removed, and the alteration of distance will not be of much importance.

## Independent Firing.

The circumstances under which it would be advisable to use this firing have been explained in the general remarks.

Advantages.

Speaking generally, it may be said that its advantages when it can be carried out, with a small number of guns under

favourable circumstances, are accuracy, simplicity, and rapidity.

Effective range. The range at which it can be used with effect depends upon—

(*a.*) The Captain of the gun.
(*b.*) The gun.
(*c.*) The size of the object.
(*d.*) The motion of the ship.
(*e.*) The wind.
(*f.*) Whether the distance and bearing alter and at what rate.

The eye, skill, and nerve of the No. 1 is a most important and unknown factor.

Distance and bearing constant. Making every allowance for wind, errors in laying, &c., there seems no reason to doubt that, with the service heavy guns, a ship 20 feet high, 60 feet beam, and 300 feet long, at 3,000 yards could be hit repeatedly, if the distance and bearing were constant and the range accurately known.

Bombarding. In the case of bombarding a town, when the object to be hit presents a considerable surface, firing might be carried on independently with effect up to the limit of the powers of the gun and carriage, the ship being heeled if necessary to give the required elevation. But as the probability of error in aiming, the difficulty of making proper allowances for wind, and certain other sources of error all increase with the distance, it will be seen how uncertain very long range fire must be, even under the most favourable circumstances.

Uncertainty of long range fire.

Bearing and distance changing slowly. In the case of a naval duel, if the distance and bearing did not alter very rapidly, under favourable circumstances, fine weather, &c., good results ought to be obtained up to about 1,500 yards, since reference to the curves of dangerous space shows that an object 20 feet high will be hit, if the error in the distance is 65 yards; also the errors due to inaccuracy in the gun would probably not be of much importance at this range.

Rapid change in distance. But if the distance varies rapidly, as in the case of a ship coming down on the beam and altering her distance at the rate of 300 yards a minute, the outside limit of effective shooting would seem to be 1,000 yards, where the permissible error in the distance with the guns now afloat is about 100 yards.

The table, p. 183, gives the change in the distance in 30″ corresponding to 10 knots speed, when ships are steaming at

different angles. It shows clearly that under certain circumstances the intervals during which a gun can be fired with a probability of hitting are very small. Thus if a ship is ordered to commence Independent Firing on the beam at another coming straight at her at a distance of 2,000 yards, in 30 seconds the enemy would be only 1,830 off, and the probability is that all the shot would go over. Nor would it suffice to pass that near distance of 1,830 yards down to the guns, because before they could be relaid the enemy would be at less than 1,700, and the shots would again miss. As before explained, the best way when commencing fire under these circumstances appears to be to order such a distance as will allow of the guns being laid before the enemy reaches it, and keeping the men in hand by not sounding the "Commence" until the enemy is within the dangerous space for that range.

**Rapid change of bearing.**

In ramming tactics, and also in a general action, the change of bearing corresponding to a change of position between the two ships, even when not complicated by putting the helm over, would be so great as to give to the captains of the guns, whose range of vision is usually limited, very little chance of catching the object at the right moment. Thus a captain of a gun may find the object obscured by smoke at the instant he would have wished to fire, he waits till the smoke clears away, and by that time he finds the enemy three points farther aft, he trains, perhaps he has to relay for elevation, and just as he is going to fire he has to alter his sight, in which case he loses his round altogether, or if he fires he misses. This points to Independent Firing not being good for close action, if ships alter their bearings rapidly, and the Nos. 1 have not a clear view.

**Plan of fixing sight.**

If the bearing and distance both change rapidly, and it is desired to use Independent Firing, it is a matter for consideration whether it would not be advantageous to adjust the sight for the particular distance within which the trajectory would never rise above the enemies' ship, and fire whenever the gun can be laid for the object within that distance which, as shown on p. 130, may be taken as 800 yards with the guns now afloat.

**Smoke.**

Smoke may interfere very seriously with Independent Firing; its effects may be minimized by choosing such a position, if not otherwise disadvantageous, that it shall interfere as little as possible with your own fire, and as much as possible with that of the enemy, or where the wind is ahead or astern, by using the special form of Independent Firing in which the guns are fired in succession from forward or aft.

This plan possesses two distinct advantages over the ordinary Independent Firing.

Firing in succession.

(1.) Where the smoke, owing to wind, or the movement of the ship, has a tendency to travel towards the bow or stern, firing in succession would often enable each gun to get a good opportunity of firing without much delay.

(2.) When the enemy is coming into view, either ahead or astern, owing to the conformation of the ship and the position of the guns, the foremost or after gun would bear before the others. This would especially be the case in ships with long batteries.

The corresponding disadvantage is loss of time.

This method would be employed when it is desired to keep up a continuous steady fire.

## Simultaneous Firing.

Definition.

This term has been adopted to describe the system of firing employed in turret ships when both the guns in each turret are fired simultaneously but the turrets work independently.

It may therefore be considered as the same in its conditions and limitations as Independent Firing as carried on in turret ships.

Advantages.

The advantages of Simultaneous Firing are—

Taking into consideration the two guns in each turret this firing carries out the principles of concentrated fire in their best form, as the sights are fixed to the turret, the guns are rigidly connected as regards direction, and are fired simultaneously by one man by mechanical means.

The effects of smoke would less interfere with the firing.

The guns in each turret carrying out their loading simultaneously would not interfere with each other.

In ships fitted with hydraulic loading gear, the guns being loaded together, Independent Firing would have no advantage and even with the hand-loading gear should one gun be fired whilst the other was being loaded the effects of the concussion on the loading numbers would be very great. Moreover, the turret could not be trained away from the enemy during loading. For these reasons it seems clear that Independent Firing should never be used by turret ships in action, although it may be retained for target practice.

## Broadside Firing.

The advantages of Broadside Firing generally are— Advantages.

The guns being fired simultaneously the effect of the projectiles is much increased.

The smoke would interfere less with the view of the object.

There is less confusion and noise, the men can be kept in hand easier, and orders can be circulated with greater facility.

The disadvantages are— Disadvantages.

It is not so accurate, because :—

1. As regards directing gun firing, the chance of error in sighting is the same as in Independent Firing, and in addition there is the great difficulty of insuring that a number of guns shall agree at the same instant both in elevation and direction.

2. With the Director the probability of error in sighting may be assumed to be practically the same as in laying with a gun, and the necessary adjustments and corrections are further probable sources of error.

* There is a loss of rapidity, as the time taken to prepare a broadside is that of the slowest gun.

The advantages of Broadside Firing by director in addition to those common to all natures of Broadside Firing, are— Advantages of firing by director.

The Captain has entire control over the fire, and can arrange to deliver it at any time and on any point he may select.

The men can be sheltered to some extent by lying down when the guns are laid.

In the case of the bearing altering very rapidly, as in that of two ships passing each other in opposite directions and at close ranges, the guns being converged on some point and fired together, there would be a probability of every shot striking, which, as pointed out, would seldom be the case if the guns were working independently under these circumstances.

The observer at the director having an all-round view can fix his attention on the object whilst the guns are being loaded, and he would often see it when out of sight from the gun deck owing to smoke, darkness, or direction.

The corresponding disadvantages are— Disadvantages.

The guns once laid cannot be altered quickly, and heel of ship arising from wind, use of helm, &c., may throw them out unless the ship be rolling enough to bring on the sights.

Skill and practice are required by the Officer at the director, as a mistake on his part will throw away the whole broadside.

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* This must not be taken to mean that a chance of delivering a broadside is to be lost for one gun, the officer at the director must exercise his discretion on this point.

It is difficult to carry out the firing satisfactorily without using electricity, which sometimes gives uncertain results, great skill and care are required to ensure success, and in action the gear may possibly be disabled.

The extra detail thrown on the Captain by having to attend specially to the guns, in addition to his other responsibilities is an objection which must not be lost sight of.

Circumstances when Broadside Firing by director would be used.

Speaking generally Broadside Firing by director would be used from ships with an average armament mounted on the broadside—

(1.) When they are manœuvring at close quarters and high rates of speed.

(2.) When the object is obscured from the gun deck.

Close quarters and high speed.

Suppose, for example, the case of two ships passing each other at a distance of 600 yards in opposite directions at a speed of 10 knots each. Taking 30° as angle of training on each side of the beam the enemy would be under fire for a period of 54 seconds only, whilst at 400 yards the period is 36 seconds, and at 200 yards only 18 seconds.

The chance of firing all the guns independently during these short periods, taking into consideration the smoke and the rapid movement of the object, would evidently be very small, whilst if the guns are laid for a pre-arranged fixed bearing they would have a much greater prospect of success.

The case taken is, of course, an extreme one, but even if ships were passing at various angles, the distance and bearing would vary so rapidly within moderate ranges that an opportunity for effective Independent Firing would seldom occur, and the limited view of the Nos. 1 through the ports would increase the difficulty.

Object obscured.

(2.) As regards this point it will frequently occur that the object is not visible from the gun deck, either through smoke, darkness, or being beyond the arc of vision of the Nos. 1, whilst at the same time the Officer at the director has a good view. Under these circumstances Broadside Firing would be a necessity.

As a special instance it may be mentioned that in the case of firing at forts in elevated positions, the line of sight would frequently be obscured by the upper part of the port, though the guns would easily bear.

Should the object remain nearly stationary as to distance and bearing, as in the case of two ships steaming in the same direction at nearly the same rate, the question as to whether Broadside Firing should be used will depend on the distance

of the enemy and on the amount of smoke, as before explained.

Broadside Firing by director would not as a rule be used— When not used.

1. When the distance exceeds 800 yards.
2. When there is not sufficient motion to bring on the sights.
3. When the bearing in which it is required to fire cannot be clearly foreseen.

As regards (1). The reasons which have led to the adoption of the fixed distance of 600 yards have been stated in the Chapter on Concentrating, where it is shown that under ordinary circumstances the firing should be fairly effective at any range up to 800 yards. Over 800 yards.

(2.) This is most important. The new class of ships which are specially designed to give a steady gun platform roll vary little, but to secure this property they have comparatively small initial stability, and are consequently very easily heeled by wind, helm, movements of men, or weights. Not enough motion.

Thus if heel be estimated after the guns have fired and whilst they are loading, it will be found that when the guns are run out a fresh heel must be given.

Three or four degrees heel is also frequently caused by the helm or the force of the wind, and this, of course, is constantly changing.

In fact, until a method of fitting the guns is adopted by which they can be elevated up to the last moment with safety, it must be considered that the new type of ship is rather opposed to effective Broadside Firing in smooth water. In some cases, however, this difficulty may be overcome by the use of the helm.

(3.) This calls for no particular remark, but may frequently occur.

In turret ships the use of Broadside Firing would seldom be requisite. In the first place the Officers and captains of the turrets have a good all round view. Secondly, the number of guns being small the smoke will seldom interfere, the more especially as Simultaneous Firing would probably be used; and, thirdly, the system of electrical firing at present fitted in these ships is difficult to keep in order. Broadside Firing in turret ships.

It may, however, occasionally be advisable for the Captain to maintain the control of the fire in his own hands, and for this purpose the system of Broadside Firing is retained.

Broadside Firing by directing gun has the advantage, that the guns instead of being fixed as in director firing, can follow the object if the bearing does not vary very rapidly, also electricity need not be used. Advantages of firing by directing gun.

Where the bearing is however altering very rapidly it may be found advisable to combine this system of firing with a fixed bearing. In this case the No. 1 of directing gun (which should always be the centre gun) would fire as usual when the guns were brought on by the movements of the ship and the enemy.

Disadvantages. The special disadvantages of directing gun firing are that—

1. Too much responsibility is thrown on the No. 1 of the directing gun.

2. The fire is not so much under control of the Captain.

With electric gear. In ships fitted with electric gear, and with firing keys in the battery, this system of firing may be carried out by electricity.

This has the advantage of enabling the broadside to be fired more simultaneously than would be the case with friction tubes; but, on the other hand, there is the possibility of failure of the electrical gear.

Directing gun firing is the only Broadside Firing which can be used in ships where there is no director, or in the event of accident to the director or electric gear.

Special method. Some officers advocate a system of firing which partakes of the natures both of Director and of Independent Firing.

On this plan the guns are laid as for Director Firing, but the Officer at the director fires whenever his sights come on without waiting for the broadside to be reported ready.

It has the advantage over Broadside Firing of rapidity, as individual guns are not kept waiting for the remainder; but against this must be put the increased probability, as in Independent Firing, of the smoke interfering with a clear view of the object, and the increased confusion and noise on the gun deck.

Comparing it with Independent Firing as carried out by Nos. 1, it is liable to the same limitations and objections as Broadside Firing arising from the guns being fixed, &c.

## Influence of Ramming on the above Systems.

Having considered the general question of which description of firing should be used in various circumstances, the next question is what should be done with the guns when there is a probability of ramming the enemy.

Two cases. Speaking generally this question may be considered under two heads.

1. When the enemy is right ahead and approaching in that line.

2. When the enemy is crossing the bow at any angle.

(1.) It is considered by many officers that the most probable way in which naval actions will be conducted in future (at least during the beginning of the fight) will be by the opposing ships or squadrons charging down upon and either ramming or scraping past each other. **End on.**

The first point in connexion with the guns is as to the bow fire, and here there is a vast difference of opinion, some Officers attaching a very great importance to bow fire at all ranges, whilst others considering the rate at which the distance would change, and the danger of smoke obscuring the movement, would not fire until at very close quarters. **Bow fire.**

As regards the broadside guns three courses have been advocated, viz. :— **Broadside guns.**

(*a.*) Laying guns on the bow.

(*b.*) Laying guns on the beam.

(*c.*) Laying guns on an intermediate bearing.

The advocates of (*a.*) argue that the guns being on the bow will have more room to move round in the event of a collision, and that the advantages of getting the broadside in as soon as possible are very great, both on account of the effect on the enemy, and on account of the danger of having the guns struck and dismounted by the passing enemy.

On behalf of (*b.*) it is urged that the guns will not move much, that when on the beam they give more cover against a raking fire, and that the broadside striking perpendicularly will be much more effective against armoured ships.

(*c.*) is a compromise which has some of the characteristics of the others.

It would seem that generally (*a.*) is the best method, and against an enemy whose side can easily be penetrated should always be employed. **Best method of laying.**

On the other hand it must be remembered that in the case under consideration of ships passing in parallel directions and at close quarters, training the guns decreases the penetration.

In all cases, however, the moral effect of the first blow would be very great, as also would be the effect produced on the enemy by the simultaneous discharge of several heavy guns close to his side.

(2.) The enemy crossing at some angle.

Under these circumstances it would seem better in all cases to have the guns trained as far forward as possible, both as bearing sooner on the enemy and being generally more effective. **Enemy crossing at angle.**

The question of how the guns should be fired would depend on their position. Those in a central battery should as a rule be fired by electricity, whilst guns mounted some way apart,

as in a ship like the "Temeraire" would be fired better independently, although originally laid on a fixed bearing, which should, as a rule, be nearly that for which the broadside guns are laid.

Turret ships. As regards turret ships, the turrets should work independently, but in the case of an enemy approaching the same considerations as to bow fire as those mentioned above hold good.

## Preparation for Ramming.

Position of guns' crews. There is a considerable difference of opinion as regards the best position of the guns' crews when preparing to ram an enemy.

One system is that of causing the men to fall out and lie down amidships, and the other is that of lying down under the shelter of the guns.

On the first plan, the men are exposed to a raking fire, to which they would be liable from the nature of the evolution, but they are less exposed to injury in the event of accident to the guns. By the second method, the guns' crews are protected from a raking fire and, so long as the gear holds, are equally safe from injury by the movement of the guns. Again, in some ships there is not room for all the guns' crews to lie down amidships. It is thus seen that the question turns on the probable effect of a collision on the guns. With the present heavy ordnance there are no data for determining this point, but it may be assumed that with the powerful breaks now supplied, and set up hand taut, as has hitherto been practised, the guns even when mounted on permanent rollers may be kept fairly under control.

Great care must however be taken to leave a certain margin for movement, the breaks not being too taut, the pauls in all cases being thrown back, and the training winch handles when not fitted for disconnecting, being removed, as well as the levers at guns not mounted on permanent rollers; in guns worked with tackles the after fall should be rove through a bolt but not hitched. The men should be instructed to keep as close to the ship's side and to the gun before them as possible, and so long as they are not standing up there seems to be no reason for their assuming any particular position.

Officers who should remain standing up, somewhere amidships, should hold on to beams overhead.

Gear overhead. It would probably be found that nearly all the gear overhead would be shaken down, causing much confusion and injury.

and this shows the importance of leaving nothing overhead except what is absolutely necessary.

It would be well if other places could be found for the arms which are brought to quarters, and for which the fittings on main decks are now placed overhead. **Arms.**

All fore-and-aft ladders not secured would probably be thrown over. **Ladders.**

Bow guns should be fired and left in, and the crews should fall out and lie down. **Bow guns.**

Stern guns on the other hand would be better out.

An important question with regard to ramming is the disposal of the engines at the last moment. Instructions on this point will be found in the Steam Manual, p. 60. **Engines.**

No rule has been laid down in the Drill Book as to laying the guns, so that the Captain must give his orders as to the description of firing which he intends to use, and he may do this by giving general instructions always to be carried out at the order "Prepare to ram" (in this case the "Alert"), or he may prefer to retain his independence of action by giving orders in each individual case. **Laying guns.**

As, however, it is most important that everyone in the ship should know that a collision is imminent, the Captain should, a short time before, sound the "Alert" on the bugle, when every officer and man in the ship should carry out his previous instructions as to lying down, &c. **"Alert."**

If the Captain's instructions on this head include laying the guns in an invariable manner, a slightly longer time should be allowed, but where this is not the case the guns are supposed to be laid beforehand by special orders.

In the event of the collision not occurring the order would be cancelled by voice tubes, &c.

Gear aloft must also be considered.

Another question touching on that of ramming is that of the liability to injury of the projecting muzzles of guns. **Projecting muzzles of guns.**

In the event of failing to strike an enemy fairly, and similarly if the enemy fails in his blow, there is a probability of the two ships scraping past each other, in which case the guns would most likely be dismounted, unless fired in time.

This is particularly the case with ships having a projecting central battery, and the possibility should always be remembered by the officer at the director.

# CHAPTER XII.

## PENETRATION OF ARMOUR.

Penetration considered generally depends on—

1. The energy due to the motion of the projectile.
2. The form of the projectile.
3. The material of the projectile.
4. The material to be penetrated, and the size of the hole.
5. The angle of impact.

### Energy.

Energy or *vis vivâ*.

To penetrate armour, the particles of iron must be moved to allow the shot to pass, that is, work must be done. Hence the perforating power of any projectile depends upon its capacity for doing work. In the case of a body in motion its energy or *vis vivâ* is the measure of the work which it will do in being brought to a state of rest, without regard to the time occupied; and, as we have seen before, p. , this varies as the weight of the body multiplied by the square of its velocity, or where W = weight of projectile, $v$ the velocity in feet per second, and $g$ the acceleration due to the action of gravity.

$$\text{Energy} = \frac{W v^2}{2g}.$$

The form of energy may be varied in projectiles fired from the same gun by the use of different weights of projectile, as within certain limits of size required for ballistic reasons, the velocity may be lowered by increasing the weight of projectile, and *vice versâ*.

Variations in energy.

Until lately it has been considered that within practical limits it was immaterial as regards penetration of armour whether the energy obtained with a given projectile was the result of a heavy shot and a low velocity, or of a light shot and a high velocity, provided the total remained the same, and this is assumed in the formulæ most generally in use.

The experiments, however, lately carried out with different weights of projectile fired from Sir W. Armstrong's new 6-inch gun at very high velocities, have led to the conclusion that

this rule is not invariable, and that there are probably for each nature of gun some limits within which the weights of the projectile and the corresponding velocities must be kept in order to obtain the maximum effect against armour. Variations in energy.

On this point the "Drill Regulations for Prussian Artillery" states that "Projectiles of different calibres require the same "amount of energy per inch of circumference to perforate the "same armour, with this limitation, that as soon as the plate "is much thicker (from $\frac{1}{5}$ to $\frac{1}{4}$) than the diameter of the pro-"jectile, the energy of the latter must be increased in a "much greater proportion to obtain penetration."

Further trials, which should commence with small calibres and thin plates, would be required to finally decide this question.

The manner in which the energy produced is varied under different circumstances, and its connexion with the different descriptions of powder, air spaces, &c., is considered in the chapter on powder.

## Form of Projectiles.

The form of projectiles is governed by the consideration of the work for which they are designed, but there is now little disagreement among artillerists on this point, and almost all have adopted an elongated cylinder with some form of ogival head and with a base nearly flat. Form of projectiles.

It has been pointed out on pp. 120, 154, that the length of the projectile must be kept within certain limits, and that these limits are at present for Woolwich ordnance from 2 to 3 calibres.

The ogival form of head may now be considered to be universally adopted for battering projectiles, the only difference of opinion being as to the amount of curve of the head. Form of head: Ogival.

The radius with which this is struck varies; in our service it is $1\frac{1}{2}$ calibre, while in the German Gruson projectiles it is 2 calibres. This form is also that most generally adopted by foreign nations.

Recent experiments carried out at Shoeburyness seem conclusively to show that projectiles whose heads are struck with a radius of 2 diameters are decidedly superior (from 5 to 10 per cent.) to the service form as regards penetration, and in the chapter on the resistance of the air it was shown that this form is also better adapted to flight.

Experiments will be carried out with projectiles, whose heads are struck with radii of three diameters.

Flat.

The only other form of head at present advocated for armour piercing purposes is a flat one.

This was used with most successful results by Sir Joseph Whitworth, combined with a very long steel projectile and a rapid twist.

The French navy also adopted a form of head very nearly flat, (slightly domed,) but it is believed, have now abandoned it.

The advantages claimed for flat-headed projectiles are—

1. They penetrate plates at an angle of impact at which a pointed-headed projectile would glance off. This will be considered under the head of oblique fire.

2. They can be fired from a depressed gun, so as to penetrate a ship some distance below the water line, which is not the case with other forms of projectile, which have a greater tendency to be deflected upwards by the water.

Disadvantages.

The points in which the ogival-headed projectile is superior to the flat-headed, are as follows:—

1st. The latter punches out a piece of the armour-plate, driving it into the backing. It is invariably found that in targets penetrated by flat-headed shot, the piece of plate punched out has passed through the target along with the shot which may greatly increase the resistance the shot meets with in passing through the backing. On the other hand the pointed ogival-headed shot cuts or rather tears through, and the plate is bent back, and forced into the backing round the edge of the hole.

2nd. Projectiles of the blunt-headed form have a strong tendency to "set up" or bulge at the head on impact, and should they do so, this materially lessens penetration; the point of a well made ogival-headed projectile is generally unaltered on impact.

3rd. As pointed out in the chapter on the motion of projectiles, p. 118, the flat-headed projectile experiences a far greater resistance in passing through the air and requires a higher velocity of rotation.

## Material of Projectile.

Material of projectile.

When a projectile strikes an armour-plate the energy of motion is employed in one of the following ways:—

1. On the plate.
2. On the projectile.

Now the object is to do work on the plate and not on the projectile, and as the whole energy is used in these two ways, the less the effect on the projectile the greater will be that on the plate. Hence the material must be such that the effect on the projectile is a minimum.

Now work may be done on the projectile either by breaking it up, or by altering its form, and its amount is correctly measured by the heat developed. Work done on projectile.

If the amount of heat generated could be exactly ascertained the loss of energy could be calculated by making use of the mechanical equivalent of heat. Sir W. Armstrong carefully measured the amount of heat generated by concussion in the following metals, and obtained an approximate estimate of the amount of work lost by conversion into heat. Heat.

*With hard tempered steel shot the energy expended in heating the projectile was about $\frac{1}{10}$ of the power stored up on striking; with softer steel the loss was about $\frac{2}{10}$, and with wrought-iron the loss was more than half. Cast-iron has hitherto eluded observation on account of the difficulty of collecting the fragments and measuring the amount of heat in them.

The loss of energy due to heating may be shown theoretically. Take the case of a 400 lb. projectile, and suppose it to be raised 100° F. on impact, neglecting the heat imparted to the plate. The specific heat of the iron employed in Palliser projectiles may be taken at ·12. Then the units of heat required to raise 400 lbs. of iron 100° F. $= 400 \times 100 \times \cdot 12 = 4800$.

Now one unit of heat $= 772$ foot-pounds.

Therefore the work expended in heating the projectile $= \frac{4800 \times 772}{2240} = 1654$ foot-tons.

From the above considerations it will be seen that the best material for the projectile is that which will neither break up on impact nor change its shape. Best material.

Chilled iron, wrought-iron, and steel, both forged and cast, have been experimented on to ascertain their respective merits for materials to make projectiles for piercing armour-plates.

Chilled iron has been adopted in this country on account of its easier manipulation, its great hardness, and its comparative cheapness of production, and when the experiments were carried out which led to its being finally chosen, the manufacture of steel had not reached its present state. Steel was then Chilled iron.

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* Treatise on ammunition, p. 193.

very expensive, and great difficulty was experienced in making a steel projectile which would neither break up nor change its form.

Forged steel. Experiments carried out more recently at Shoeburyness with 9-inch projectiles with ogival heads and of equal weights, made of steel or chilled iron by different manufacturers, and fired against an armour-plate of wrought-iron 12 inches thick, have shown that forged steel is the best material for piercing wrought iron. The chilled iron shells generally break up on impact, while the steel shells rarely do so, and then always in large pieces, in some cases the head only separating from the body. The shells made of Whitworth forged steel gave the best results, and were the only samples of steel which fairly pierced the plate and remained perfect without any sensible alteration in shape. The penetration with steel projectiles which neither break up nor sensibly alter their shape is greater than with ordinary chilled projectiles, and when the armour is arranged in two or more thicknesses, with backing between, the advantage of not breaking up is still greater. A forged steel shell which could carry a bursting charge of gun-cotton through a ship's side would be a most important addition to the power of artillery.

Again the 12″·5 38-ton gun was fired against a target composed of a 4″ plate, air space of 4′ 7″, 10″ plate, the charge being 175 lbs., and a chilled projectile of 800 lbs. weight being used. The projectile passed through the first plate and broke up in doing so, only making a splash on the second plate.

The selection of steel as the best material for armour piercing projectiles, is supported by the practice of foreign governments. (*Vide* Table.)

In the experiments with the new Armstrong 6-inch gun, an 84 lbs. forged steel shell passed through a 10-inch iron plate, penetrated 6 feet into a sand butt in rear, and was dug out almost uninjured; while a similar projectile, weighing 80 lbs., perforated an 8-inch plate, and was found to be set up at the shoulder only ·05 inch. These projectiles were not weakened in any way by stud holes or grooves for bands, being rotated by a gas-check.

'al form. A special form having a small and extremely hard steel point cast or screwed into the point of the projectile has given recently very good results.

Any soft metal coating, band, or gas-check, on the projectile adds to the weight without increasing its useful effect on armour, as its energy would probably be all expended : changing its form.

Projectiles are now always made hollow. The shape of the cavity which has been adopted as being most favourable to the strength of the projectile will be seen in plate p. 360. Hollow projectiles.

The following Table gives some particulars as to form, &c. of battering projectiles for various descriptions of guns.

| Guns. | Length of Battering Projectile in calibres. | Radius of Ogival Head in calibres. | Material. |
|---|---|---|---|
| Woolwich late patterns | 2·4 to 2·6 | $1\frac{1}{2}$ | Chill. |
| Armstrong 6-in. - | 1·84 to 2·86 | $1\frac{1}{2}$ | Steel and chill. |
| French, Mod. 1870 - | 2·2 to 2·4 | 1·6 | Steel and chill. |
| German, Gruson - | 2·5 | 2 | Chill. |
| „ , Krupp latest - | 2·8 to 3·5 | 2 | Chill and steel. |
| Austrian - - | 2·5 to 2·8 | 2 | Steel or chill for B.L. M.L. have chill $1\frac{1}{2}$ cal. |
| Russia - - - | — | 2 | Chill and steel (equal proportions). |
| Italy - - - | — | 2 | Chill (going to have steel). |

## Penetration.

The relative advantages of cast-iron, wrought-iron, and steel, and the various methods of arranging them for resisting the fire of heavy guns, will be considered in the chapter on "Armour."

The great variation in the projectiles, plates, masonry, &c. makes it extremely difficult to obtain accurate coefficients of resistance, but from numerous experiments various empirical formulæ have been obtained from which the probable amount of penetration in any given case can be approximated to with more or less exactness.

Three methods of measuring effect.

The work done in punching a hole through an armour-plate depends upon the area and thickness of the plate and upon the dimensions of the hole.

The punching action may be considered in three ways: (*a*) as cracking the plate circumferentially, (*b*) as exerting a wedging action over all its sectional area, and (*c*) as moving a given volume of metal. Thus, the three methods of viewing the subject depend respectively upon whether linear, square, or cubical dimensions are taken.

Energy per inch.

The first is that usually adopted in England in comparing the power of guns, which is estimated accordingly by the foot-tons of energy per inch of circumference. Thus

Let W = weight of projectile.
$r$ = radius of „
$v$ = velocity of same at any point.
E = kinetic energy „
$e$ = kinetic energy per inch of shot's circumference.

$$t = \left\{\begin{array}{l}\text{thickness of iron plate the pro-}\\ \text{jectile can pierce - -}\end{array}\right\} = \text{perforation.}$$

$$t' = \left\{\begin{array}{l}\text{thickness of iron it can penetrate}\\ \text{without perforation - -}\end{array}\right\} = \text{penetration.}$$

$$\text{Then } E = \frac{W \cdot v^2}{2\,g} \text{ and } \frac{E}{2\,\pi\,r} = e.$$

Captain A. Noble.

Captain A. Noble, F.R.S., from the results of a series of experiments lately carried out with the 8″ and 6″ Armstrong B.L. guns against plates of thicknesses from 4 to 16 inches, together with a few rounds with the 9″ and 12″.5 M.L. guns, arrives at the following conclusions, which are embodied in the curves given in the diagram opposite, and which he further represents by the equation—

$$e = 2{\cdot}141\ t^{1{\cdot}615}.$$

Where $t$ is between 4 and 10 inches, and by

$$e = 0{\cdot}860\ t^{2{\cdot}035}.$$

Where $t$ lies between 10 and 20.

He however points out that caution must be exercised in assuming that any such simple equation can be taken to represent the actual law of penetration; and also that the qualities of projectiles and plates, and especially the latter, vary greatly, and frequently lead to anomalous results.

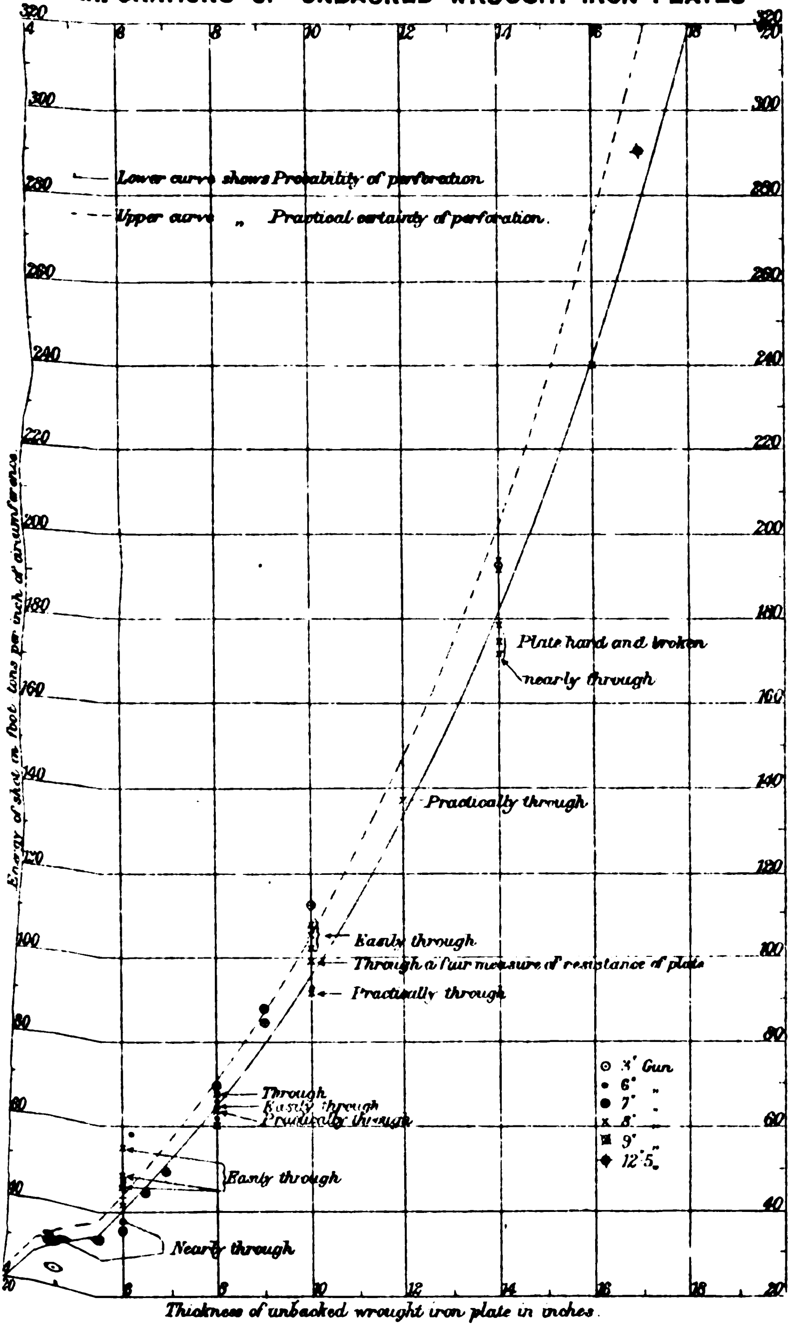
Penetration.

It is to be remembered that this formula is calculated to show the thickness of plate that can be *perforated*, not the depth to which a projectile will *penetrate* in a plate too thick for it to perforate.

As regards this point an approximation may be got by allowing a deduction of about 10 per cent., or

$$t^1 = t \cdot \frac{9}{10}.$$

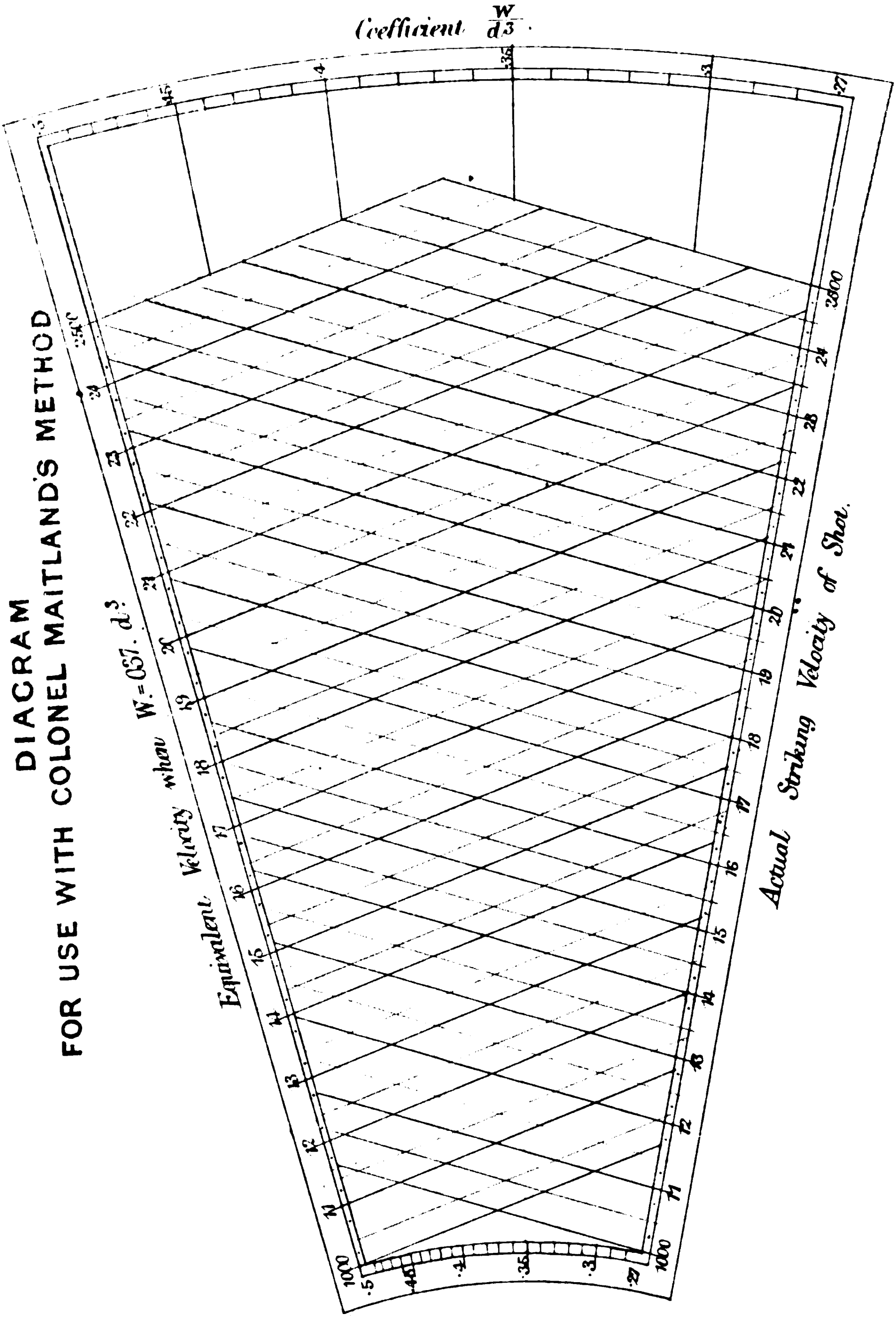
## CAPTAIN A NOBLE'S DIAGRAM OF PERFORATIONS OF UNBACKED WROUGHT IRON PLATES






To face

DIAGRAM
FOR USE WITH COLONEL MAITLAND'S METHOD




To face page 245.

As an example of determining the thickness of plate that may be perforated, suppose the energy per inch of circumference of a Palliser shell on impact is known to be 165 ft. tons, then from Captain A. Noble's diagram there is practical certainty of perforating about 12·6 in. of iron and a probability of piercing 13·2 in. **Example.**

The actual *penetration* of the above shell into a wrought-iron armour-plate of considerable thickness may be approximated to at about 11·7 ins.

Recent experiments against unbacked wrought-iron plates have established the following law, which is stated by Col. Inglis, R.E., as follows :— **Col. Inglis, R.E.**

"For each proportion of diameter of shot to thickness of plate (whatever these dimensions may be), a constant amount of energy is required for the displacement of an unit volume of plate, provided that the ratio of shot's weight to calibre of gun be within the usual limits."

This is equivalent to saying that with a given velocity if a 9-in. shot perforate a 9-in. plate, a 12-in. shot will pierce a 12-in. plate, provided that the ratio of weight to calibre be the same in each projectile.

Lieut.-Col. Maitland, R.A., has independently arrived at the same conclusion, and his method of illustrating the question is more general but not so accurate as that of Col. Inglis, as will be seen by comparing the diagrams and tables attached. **Lieut.-Col. Maitland, R.A.**

The table is based upon the experimental fact that for the same velocity the perforation is in all cases approximately proportionate to the diameter of the projectile, so long as the ratio $\frac{w}{d^3}$ is constant.

This quantity $\left(\frac{w}{d^3}\right)$ may be looked upon as a unit volume weight, and in the most reliable experiments had a value $=\cdot 37$, which has therefore been taken as the normal one. For any other value the equivalent velocity mnst be determined, which can be readily done by means of the diagram.

Use of diagram.—Take the value of $\frac{w}{d^3}$ for the required projectile, and place a straight edge to these values on the arcs; run the eye up the line indicating the given velocity to its

Lieut.-Col. Maitland.

intersection with the straight edge, then read off the velocity giving equivalent energy when $w = \cdot 37 \times d^3$.

Use of table.—From the table take the value of $k$ corresponding to this velocity; this value, multiplied by the diameter of the projectile, gives the thickness of unbacked wrought-iron solid plate that will be just perforated by the given projectile striking with the given velocity.

TABLE for use with Col. MAITLAND'S DIAGRAM.

| Striking velocity when $w = 37d^3$. | Factor $k$. | Striking velocity when $w = 37d^3$. | Factor $k$. | Striking velocity when $w = 37d^3$. | Factor $k$. |
|---|---|---|---|---|---|
| 1,000 | ·85 | 1,550 | 1·4 | 2,050 | 1·9 |
| 1,050 | ·9 | 1,600 | 1·45 | 2,100 | 1·95 |
| 1,100 | ·95 | 1,650 | 1·5 | 2,150 | 2·0 |
| 1,150 | 1·0 | 1,700 | 1·55 | 2,200 | 2·05 |
| 1,200 | 1·05 | 1,750 | 1·6 | 2,250 | 2·1 |
| 1,250 | 1·1 | 1,800 | 1·65 | 2,300 | 2·15 |
| 1,300 | 1·15 | 1,850 | 1·7 | 2,350 | 2·2 |
| 1,350 | 1·2 | 1,900 | 1·75 | 2,400 | 2·25 |
| 1,400 | 1·25 | 1,950 | 1·8 | 2,450 | 2·3 |
| 1,450 | 1·3 | 2,000 | 1·85 | 2,500 | 2·35 |
| 1,500 | 1·35 | | | | |

Perforation = $k.d.$

Tables showing the energy, whence the penetration is easily calculated by Captain A. Noble's diagrams, are given for various guns on pp. 272–290, and the energy is also shown in the form of curves in diagrams .

Common shell.

The penetration of common shell is considerable, although not to be compared with that of Palliser shell under similar conditions. The large bursting charge in the common shell renders it particularly destructive in cases where the armour-plate can be pierced. It may be fired with or without a percussion fuze. With the general service percussion fuze the burst takes place quicker than when no fuze is used.

The 10-in. M.L. gun, with battering charge and common shell, is capable of perforating a 5-in. iron unbacked armour-plate at 70 yards.

## TABLES.

TABLE showing Approximate Energy in Foot-tons per Inch of Shot's Circumference required for the Perforation of Unbacked Iron Plates.

Energy to perforate unbacked wrought iron.

| Thickness of plates in inches. (1.) | According to Captain A. Noble. (2.) | To penetrate at angle 60° with plate. Results of (2) $\times \frac{1}{\sin^2 60°}$. | According to Prussian Drill Regulations. |
|---|---|---|---|
| 4 | 22 | 29 | 22 |
| 5 | 30 | 40 | 34 |
| 6 | 40 | 53 | 47 |
| 7 | 51 | 68 | 61 |
| 8 | 64 | 85 | — |
| 9 | 78 | 104 | — |
| 10 | 95 | 126 | — |
| 11 | 115 | 153 | — |
| 12 | 137 | 182 | — |
| 13 | 160 | 213 | — |
| 14 | 185 | 246 | — |
| 15 | 213 | 283 | — |
| 16 | 245 | 326 | — |
| 17 | 280 | 372 | — |
| 18 | 320 | 426 | — |
| 19 | — | — | — |
| 20 | - | — | — |

TYPES OF SHIPS' ARMOUR, with the Energy per Inch of Circumference required for Perforation.*

Energy to perforate ship's armour.

| Inches of iron in target. | Inches of wood in target. | Skin of iron. | Energy per inch for perforation. | Inches of iron in target. | Inches of wood in target. | Skin of iron. | Energy per inch for perforation. |
|---|---|---|---|---|---|---|---|
| | | ins. | ft. tons. | | | ins. | ft. tons. |
| 4·5 | 10 | none | 34 | 12 | 12 | $1\frac{1}{2}$ | 182 |
| 5 | 9 | $\frac{1}{2}$ | 42 | 13 | 14 | $1\frac{1}{8}$ | 204 |
| 5·5 | 10 | 1 | 51 | 14 | 12 | $1\frac{3}{8}$ | 226 |
| 6 | 12 | $\frac{1}{2}$ | 60 | 15·5 | 12 | $\frac{3}{8}$ | 237 |
| 6 | 30 | none | 70 | 14 | 10 | $1\frac{1}{8}$ | 259 |
| 8 | 10 | $\frac{3}{4}$ | 84 | 17 | 19 | $1\frac{3}{8}$ | 306 |
| 8·5 | 15 | none | 96 | 18 | 18 | $1\frac{3}{8}$ | 330 |
| 9 | 10 | 1 | 112 | 21·5 | 14 | 1 | 395 |
| 10 | 9 | $1\frac{1}{4}$ | 126 | 22 | 18 | $1\frac{3}{8}$ | 437 |
| 11 | 12 | 1 | 144 | 24 | 12 | $1\frac{3}{8}$ | 465 |
| 9 | 9 | $1\frac{1}{2}$ | 153 | | | | |

* Sladen, p. 106.

German table. The Prussian Drill Regulations give the following Table of Energy required per Inch of Circumference of Projectile to perforate Wrought-iron Plates with medium backing.

| Thickness of plate in inches. | Energy required. | Thickness of plate in inches. | Energy required. |
|---|---|---|---|
| 4 | 38 | 9 | 112 |
| 5 | 50 | 10 | 135 |
| 6 | 63 | 11 | 158 |
| 7 | 77 | 12 | 186 |
| 8 | 94 | | |

## Oblique Fire.

Angle at which a projectile will glance. The angle at which a projectile will glance on striking a structure depends upon the form of the head, the material of the projectile, its velocity, and upon the hardness, rigidity, and solidity of the structure.

High velocities. For very high velocities there would seem to be hardly any limit to this angle, and this may be explained as follows:—

For high velocities the work done in a small interval of time is so large that the particles of metal have no time to support each other, and may be considered to flow away, thus allowing the projectile to bite.

The hardness of the face of the plate will exercise an important influence on this point, as this quality prevents the ready motion of the particles of metal.

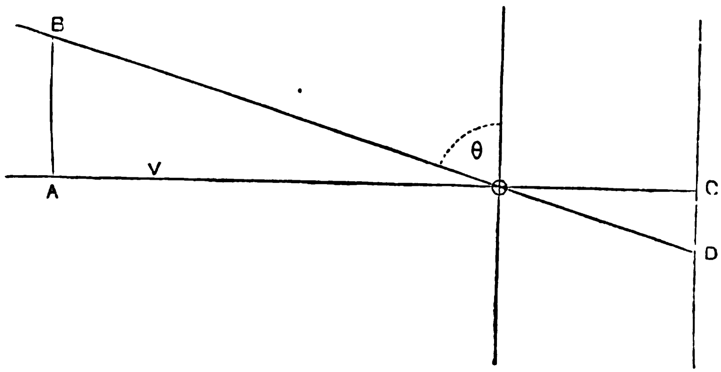
Ordinary velocities. The case of projectiles fired with ordinary velocities against wrought-iron plates will now be considered more fully, and the remainder of this chapter must be taken as referring only to penetration under these conditions.

Oblique fire. Sufficient experiments have not been carried out to give any decisive data as to the exact angle at which the various forms of projectile fired with ordinary velocities will penetrate a wrought-iron armour plate, but it is stated that a steel flat-headed projectile will penetrate at an angle of impact with the surface of the plate of about 30°, while the ogival-headed projectile of the best form will hardly penetrate at a less angle than about 40°.

Different formulæ. Two formulæ varying considerably from each other are given for the velocity required to penetrate an armour plate struck obliquely. This variation arises from uncertainty as to the behaviour of a projectile on impact under these circumstances.

The first formula is calculated on the supposition that a projectile on striking a plate obliquely turns in towards the plate, when its point is arrested and penetrates normally, and the second supposes that it continues its straight course and penetrates the plate obliquely.

Projectile supposed to turn on striking.




Suppose the projectile is travelling in the path B *o*, and makes an angle of incidence $\theta$ with the surface of the plate. Let A *o* represent $v$, the velocity required to pierce the armour plate with right-angled impact A C, then the energy required per inch of circumference of projectile or

$$e = \frac{Wv^2}{2g \pi d}.$$

Now take the first case, *i.e.*, the projectile on striking turns in and penetrates normally in the line OC.

Then estimating the velocity required for perforation along line B *o* we get

$$v^1 = \frac{v}{\sin \theta};$$

substituting this in the above equation we get for oblique perforation

$$E = \frac{Wv^2}{2g\pi d \cdot \sin^2 \theta}$$

so that in this case the number of foot-tons per inch of circumference to perforate an armour plate obliquely is found by dividing the number of foot-tons required for perforation by right-angled impact by the square of the sine of the angle of impact.

Projectile supposed to perforate plate in line of fire.

On the second supposition, that the projectile goes on its course without deflection, and passes through the plate in the line OD, we have simply a plate of the thickness

$$OD = \frac{OC}{\sin\theta}$$

opposed to the projectile, and in this case the energy per inch of circumference for oblique perforation will be

$$\frac{W\,v^2}{2g\pi d\,\sin\theta}.$$

*This formula gives the best results for flat-headed projectiles and comparatively thin armour plates.

In 1872 the 12″ 35-ton gun was fired at an angle of incidence of 60° against a target consisting of 8″ plate, 6″ wood, 5″ plate, 6″ wood.

On striking at angle of 60° the projectile turned in at an angle of 70°, passed through 8″ plate, and penetrated 3″·5 into the 6″ plate, then broke up.

Extract from Prussian Drill Regulations.

The Prussian Drill Regulations state that "The number of " foot-tons per inch of circumference required to perforate " armour obliquely is obtained by multiplying the number " required for right-angled impact by $\frac{1}{\sin^2\theta}$ where $\theta$ is angle " of impact.

"This has been obtained by experiment."

"Table of factors by which to multiply for oblique impact $\left(\frac{1}{\sin^2\theta}\right)$:

| $\theta$ | factor | $\theta$ | factor |
|---|---|---|---|
| $\theta$ = 85° | factor 1·008. | $\theta$ = 60° | factor 1·33. |
| 80° | „ 1·03. | 55° | „ 1·50. |
| 75° | „ 1·07. | 50° | „ 1·7. |
| 70° | „ 1·13. | 45° | „ 2·0. |
| 65° | „ 1·22. | | |

"For instance, from table of penetration, a 7″ plate with medium backing requires 77·5 foot-tons for perforation; using the above table of factors it will require 82·9 to perforate the same plate at an angle of 75°.

"Experiment has shown that our chilled shells when striking with sufficient velocity, even at an angle of 45°, do not glance off, but either penetrate or perforate them."

* Sladen, Ordnance and Gunnery.

The following Table gives the Penetrations up to 2,734 yards for angles of impact of 90° and 60° from the following German guns :—

German table of penetration.

| Gun. | Weight of chilled shell. | Charge. | Muzzle velocity. | Target, wrought-iron plates with medium backing. | Range up to which the target will be perforated. | |
|---|---|---|---|---|---|---|
| | | | | | At right angles. | At oblique impact under 60°. |
| | lbs. | lbs. | f.s. | inch. | | |
| Long 15 c.m. hooped gun. | 78·26 | 18·74 | 1,624 | 4 | 2,625 | 1,367 |
| | | | | 4½ | 1,969 | 875 |
| | | | | 5 | 1,422 | 437 |
| | | | | 5½ | 984 | 109 |
| | | | | 6 | 547 | Not. |
| | | | | 6½ | 219 | Not. |
| Long 21 c.m. hooped gun. | 217·15 | 41·89 | 1,463 | 6 over | 2,734 | 1,805 |
| | | | | 7 | 2,187 | 875 |
| | | | | 8 | 1,312 | 109 |
| | | | | 9 | 437 | Not. |
| 28 c.m. gun - | 515·9 | 88·19 | 1,393 | 10 | 2,352 | 547 |
| | | | | 11 | 1,258 | Not. |
| | | | | 12 | 383 | Not. |

# CHAPTER XIII.

## EFFECTS OF FIRE.

### DEFINITIONS.

Definitions.

The following terms are used to define the different descriptions of artillery fire:—

With reference to direction.

Artillery fire, as to its direction with reference to the horizontal plane, is called—

*Front*, when it strikes the front of an object, or nearly so.

*Oblique*, when the object is struck in front but not perpendicularly.

*Enfilade*, when the fire is directed along the line of the object fired at. This is also known as *raking* fire when applied to ships.

*Reverse*, when the object is struck from the rear.

With reference to trajectory.

With reference to the trajectory, it is defined in works on artillery as—

*Direct*, with service charges, at all angles of elevation not exceeding 15°.

*Curved* or *Indirect*, from guns with reduced charges, and from mortars and howitzers at all angles of elevation not exceeding 15°.

*High angle*, from guns, howitzers, and mortars, at all angles of elevation exceeding 15°.

For naval purposes.

The definitions with reference to the trajectory are not, however, applicable to naval purposes, and they may be altered thus:—

*Direct* fire is that from guns where the angle of descent of the projectile is less than 8°.

*Depressed* fire is that from guns which are depressed below the horizontal plane.

*Curved* fire is that from guns, howitzers, or mortars, where the angle of descent of the projectile is between 8° and 20°.

*High angle* fire is where the angle of descent is greater than 20°.

In this work the above terms will be used in the latter sense.

Artillery fire.

For naval purposes artillery fire may be considered under five heads:—

Against the armoured side of a ship.
Against the unarmoured side of a ship.

Against fortifications of stone or iron.
Against earthworks.
Against boats or bodies of men, including fire from field or boats' guns.
Curved and high-angle fire.

## Against the Armoured Side of a Ship.

This subject is discussed in Chap. XII. and XVI., and it will, therefore, be only necessary to refer here to certain special experiments. Against armoured side.

Chilled shot may in our service be considered as obsolete, as for the newer classes of guns there is only one class of battering projectile which may be fired either filled or empty.

Empty shell or shot would only be fired where a filled shell is not available, as the penetration of the filled shell is nearly the same, and the resulting effect is much greater.

Chilled empty shell will, however, break up on passing through an iron plate of even moderate thickness, and the fragments would probably do more execution than if it remained unaltered in form.

Armour piercing shell then would always be used against an armoured ship when practicable, common shell being practically ineffective, notwithstanding the experiments mentioned on p. 246.

Different reasons have been assigned as to the cause of the explosion of the bursting charge in Palliser shells. It is not due to the shell breaking up, as the same action takes place in Whitworth's hardened steel shells, which do not break up. The metal of the shell does not acquire a sufficiently high temperature on striking, so the explosion is not due to heat transmitted from the shell; the most probable cause appears to be the violent concussion of the powder on striking. Bursting of Palliser shell.

On firing the powder sets back, forming a dense compact mass so hard that sometimes it cannot be cut by a copper tool; on the shell striking the plate, this hard mass of powder would be dashed forward and pressed into the contracted part of the shell, thus undergoing great friction, probably sufficient to tear the bag, and thus cause the powder to explode.

If forged steel be adopted for the material of battering projectiles, it will probably be necessary to employ gun-cotton for the bursting charge, as the strength of the shell is greater than the maximum pressure which can be produced by the explosion of gunpowder under these circumstances, and the only effect produced is to blow out the base-plug. Forged steel shell.

Gun-cotton, however, will not explode on impact in a similar manner to gunpowder, and therefore a fuze would have to be employed.

Armour piercing projectiles striking filled shell.

Experiments.

The following experiments were carried out to ascertain the effect of an armour piercing projectile, after passing through an armoured ship's side, on filled shell.

The target was a section of the "Warrior"; the projectiles fired at, viz., 9-inch common shell filled, some fuzed with Pettman fuzes and others plugged, and 9-inch Palliser shell filled, were placed in a row on their bases, 2 inches apart, in rear of the target, at 2 feet from the inner skin. The gun used was a 9-inch M.L.R., placed at 10 feet from the target in order to ensure hitting the exact spot required. The charge was 38½ lbs. R.L.G., to give a striking velocity equivalent to that of the battering charge of 43 lbs. at 200 yards. The projectiles fired were Palliser shell, some filled and others empty. At each round the target was penetrated, and the projectile struck exploded, as did also that on its right and left side. In several cases the Pettman fuze did not ignite in the shell, which were exploded by the impact of the projectile fired. Empty Palliser shell were then placed between the filled shell, with the view of confining the explosion to the shell struck. This had the desired effect: the filled shell struck, whether common or Palliser, was exploded and the empty shell on either side of it thrown violently down, and in some cases cracked, but they protected the other filled shell, which were thus prevented from exploding.

In another experiment a pile of 42 9″ common shell filled, placed behind a target representing the "Warrior's" side, was fired into by a 9″ gun, with Palliser shell and battering charge. There was a violent explosion, but it was considered that only those shells which were actually struck by the projectile exploded.

Conclusions.

The result proved that the circumstance of having filled shells fuzed does not render them more liable to be exploded if struck by a projectile than if they had been only filled and plugged. Also that the destructive effect produced by an armour piercing projectile striking and bursting amongst rows of filled shell placed behind the armoured side of a ship may be reduced to a minimum by placing an empty Palliser shell, or a Palliser shot, between each pair of filled shell, an arrangement which apparently confines the explosion to the shell actually struck. This plan has since been adopted in the Navy.

## Against the Unarmoured Side of a Ship.

The targets against which fire would be directed may be considered of three classes:— Against unarmoured side.

1. The ordinary unarmoured side of a ship, consisting either of iron exterior plate of about 1 in. and with an interior lining of wood or thin iron, or of wooden timbers and planking.
2. The side specially constructed to avoid splintering, as in the case of the new belted ships. This side consists solely of an iron plate ¾ to 1 in. in thickness.
3. A side with some special protection, such as coal.

(1.) The effect of projectiles would usually be greater with an ordinary than with a specially constructed side. Ordinary.

### *Special Form of Side.*

(2.) Experiments were carried out in 1875 against No. 39 target representing the specially constructed side of an unarmoured ship, such as the "Shannon." Specially constructed "Shannon" target.

There were two targets, each 10′ broad and 8·5′ high, one on the right of 1 in. iron, and the one on the left of ¾ in. iron. They were fastened without rivets. They were connected together by a target of ½ in. deal boards, so that the total frontage fired at was 57 feet. A similar target was placed behind to represent the reverse side of the ship, and old guns were mounted in the ports with dummies to represent the crew.

| No. | Gun and Range. | Charge. | Struck target with velocity due to yards. | Projectile. | Fuze. | Number of rounds. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | lbs. | | | | | |
| 1 | ·65 Gatling, 200 yds. | — | 200 | — | — | 2 drums | No effect. |
| 2 | 64-pr. „ | 10 | 200 | Case | — | 2 | No effect, except through port. |
| 3 | 9-in. „ | 30 | 200 | Case | — | 2 | No effect on 1-in part. Nearly through ¾-in. |
| 4 | „ „ | 27·5 | 500 | Shrapnel | R.L. | 1 | At 1-in. part; burst: effect great. |
| 5 | „ „ | — | — | — | — | 1 | At ¾-in. part; broke up. Did not ignite bursting charge; effect great. |
| 6 | 64-pr. „ | 6 | 1,000 | Common shell filled | R.L. | 1 | At 1-in. part; burst; effect great. |
| 7 | „ „ | „ | „ | „ | „ | 1 | Did not ignite burster, but broke up, effect great. |
| 8 | „ „ | „ | „ | „ | „ | 1 | Broke up, burster did not ignite, not much effect. |

The following remarks were made by the Superintendent of Experiments:—" Both sections of target are proof against ·65 Conclusions.

"Shannon" target.

Gatling and case from 64-pr., but ¾ in. section was nearly penetrated by 9 in. case at 200 yards. Greatest effect was from 9 in. shrapnel, which broke up on passing through the first side and made numerous holes from splinters in the opposite side, sweeping away the gun's crew, and in one case dismounting the gun. Effect on traverses was very small, but would have been greater with oblique fire."

Further experiments.

*Experiments in 1876.

Target repaired and size as before, but right portion was of two ½-in. thicknesses of iron, and left of the same thicknesses of Bessemer steel.

A mantlet of 4½ in. tarred rope was hung up close in rear of front target, and another between the two targets, in what would be the midship part of ship.

| No. | Gun. | Charge. | Struck with velocity due to yards. | Projectile. | Fuze. | Part of target fired at. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | lbs. | | | | | |
| 1 | 9", 200 yds. | 27·5 | 500 | Shrapnel | R.L. | Iron | Burst on striking, effect very great. |
| 2 | 64-pr. " | 8 | 500 | " | " | Steel | Burst on striking, effect very great. |
| 3 | — | 6 | 1,000 | Common | " | " | Broke up and charge ignited amidships, effect great. 6 feet of centre mantlet destroyed and set on fire. |
| 4 | 64-pr. 200 yds. | " | " | " | " | " | Broke up and charge ignited 5 feet inside, effect very great. |
| 5 | 9" " | 30 | 200 | Case | " | Steel | No effect, 19 hits. |
| 6 | " " | " | " | " | " | Iron | No effect, 3 hits. |
| 7 | 64-pr. " | 6 | 1,000 | Common | " | " | Struck and burst 6 yards in front of target, effect inside great. |
| 8 | " " | " | " | " | " | " | Burst in striking, effect very great. |
| 9 | " 100 yds. | 8 | 450 | " | " | Steel | At angle of incidence, 25°. glanced and burst. |
| 10 | " " | " | " | " | " | " | At angle of incidence, 30°, burst on striking. Through, effect very great. |
| 11 | " " | " | " | " | " | " | At angle of incidence, 25°. grazed and burst. Made opening in side 7′ × 8″; no effect inside. |
| 12 | " " | " | " | " | " | Iron | At angle of incidence, 45°. Through; burst, effect very great. |
| 13 | " " | " | " | " | " | " | At angle of incidence, 25°, Through; burst, effect good. |
| 14 | " " | " | " | " | " | " | At angle of incidence, 20°. Through; burst, effect good. |
| 15 | " " | " | " | " | Plugged | Steel | Through. Did not burst or break up; not much effect. |
| 16 | " " | " | " | " | " | " | Broke up, but did not burst, effect good. |
| 17 | " " | " | " | " | " | " | Burst, effect good. |
| 18 | " " | " | " | " | " | Iron | Broke up, effect good. |
| 19 | " " | " | " | " | " | " | Broke up, charge did not ignite, effect good. |
| 20 | " " | " | " | " | " | Steel | At angle of incidence, 45°. Burst after passing through. effect good. |

* *See* Proceedings of D. of A., 1876, pp. 9 and 85.

The following remarks were made by the Superintendent of Experiments:—"The steel was of very good quality. The holes made in it were more jagged than in the iron, but the steel had more resistance to penetration than the iron, both to case shot and to fire at all angles. Two rounds of 64-pr. common shell at angle of 25° failed to penetrate it, while the iron was penetrated at angles of 25° and even 20°. It is however doubtful whether this is an unmixed advantage. Round 11 which failed to penetrate, opened the ship's side 7 feet long and 8 inches wide. Remarks. Side.

"*Mantlets* next ship's side seemed to be worse than useless, as they were usually set on fire and failed to stop splinters. Centre mantlets were more useful, but meshes were too open and many shrapnel balls went through. They should be rendered uninflammable. Mantlets.

"*Traverses.*—1 in. traverses seem to answer well in stopping splinters from oblique fire. Three shells at angles from 20° to 30° penetrated target, but only one splinter passed through a traverse (round 9). Traverses.

"*Projectiles.*—13 shells were fired with R.L. fuzes, they burst in every case and shells broke up small; 3 64-pr. common shells filled and plugged were fired, they broke into large fragments and charge did not ignite. Two 64 shells with G.S. fuze* were fired, the one at steel portion exploded, the other at iron portion broke up but did not explode. Experiments were afterwards carried out with a second plate 1 in. thick placed 2′ 6″ in rear of iron portion of target. This was of little effect." Projectiles.

The mantlets, as now supplied, are of untarred rope, and are rendered uninflammable by a chemical process.

The above experiments show that shell fire against unarmoured ships, even where especially constructed to avoid splintering, and with traverses and mantlets, is most formidably effective, and that shrapnel were as much so as common shell, as regards the actual fragments, but the moral effect of the large bursting charge of a common shell would be an important element. Deductions.

These experiments, however, being carried out with a much more sensitive fuze than the G.S. percussion fuze, which is that used with service heavy guns, do not give much information as to the effect of shell fuzed with the latter.

No reliable data have been obtained as to the distance inside a ship at which a heavy shell fuzed with G.S. fuze

* Report does not state which are the rounds alluded to.

Shannon target.

would explode, but it is a much slower acting fuze than the R.L.

The effect of the shell which broke up was also very great, and in some cases the bursting charge exploded after this had occurred, setting fire to the mantlets, &c.

The common shell, from the 10-in. and heavier natures, might, however, not break up in a similar manner, as they are stronger.

*Form of Side with special protection.*

Specially protected side.

3. Various plans have been proposed to protect the machinery of an unarmoured ship and to prevent the inflow of water if penetrated low down.

Coal target experiments.

As regards the first object the best results obtained have resulted from a protection formed by placing loose coal between the outer side and an inner bulkhead.

64-pr. gun.

Experiments carried out in 1877 with a 64-pr. gun fired with 10 lb. charge at 150 yards showed that by placing $\frac{3}{8}''$ iron plates at intervals of 2′ 6″ and filling the intermediate spaces with loose coal, the machinery would be protected by 5 feet of coal.

90-cwt. gun.

Further experiments were carried on in 1878 using a 7″ 90 cwt. gun at 100 yards range against a target constructed as shown in sketch.

The results were:—

Round 1. 24 lb. charge, Palliser shell filled; through side, two $\frac{3}{8}''$ plates, and 8′ coal; broke up or burst.

Round 2. 14 lb. charge, double shell, G.S. fuze; through side, one $\frac{3}{8}''$ plate, and 6′ of coal; burst.

Round 3. 24 lb. charge, double shell R.L. fuze; through side, one $\frac{3}{8}'$ plate and $4\frac{1}{2}'$ of coal; burst.

The coal was not ignited. The double shell seemed to turn on striking, and in round 3, it turned upwards and blew up part of the plate representing the deck above.

The shell with the R.L. fuze exploded quicker than that with G.S.

Patent fuel.

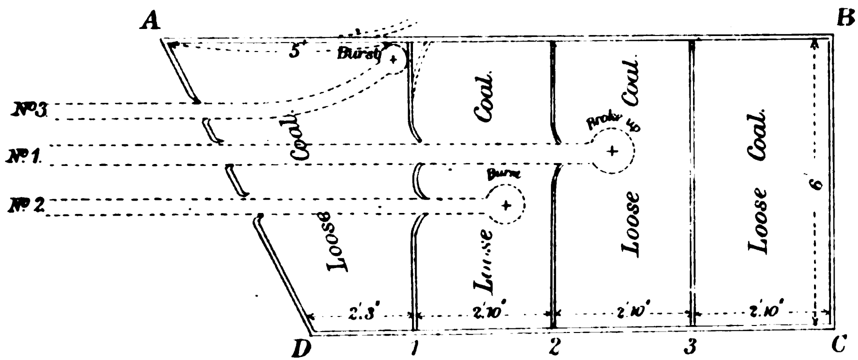
Similar experiments were at the same time carried out against a target of the same description, except that the loose coal was replaced by blocks of patent fuel built up.

The penetration into these was greater than into the loose coal.

To face page 258

## OBERON COAL TARGET No. 1.

+ *shows extreme penetration of each round.*




| | |
|---|---|
| *Round 1. Chilled shell 24 lb. charge.* | *A D, side of ship.* |
| *" 2. Double shell G.S. fuze. 14 lb. charge.* | *A B, C D, ½ in. plate.* |
| *" 3. " " R.L. " 24 " "* | *1, 2, 3, C D, ⅜ in do.* |

*Round 3 forced up deck plate and forced back the top of No. 1 plate.*

In order to prevent the influx of water when struck below the water line, experiments were carried out against a double side stuffed (*a*) with oakum, (*b*) with cork. Coffer dam side.

The gun used was the 64-pr. fired with great depression, and the following conclusions were arrived at.

1. Cork, 4′ thick, was quite useless.
2. Two feet of white oakum, soaked in chloride of calcium, was found to give considerable protection against flow of water. It was jammed into the hole in the inner side and was not set on fire.
3. Shell fuzed with R.L. fuze passed through the side, 2′ oakum, and a thin iron plate, before the burst was developed.
4. Tarred oakum, even when soaked as above, was set on fire.

## Against Fortifications of Stone or Iron.

*Experiment carried out, 20/7/77, at Shoeburyness with Palliser shell, weighted with sand, fired from 38-ton 12″·5 gun with 175 lb. charge. Range, 49 yards. Experiments against iron and stone.

Target.—One 4½″ iron plate placed in front of a granite wall 7′ 6″ high, 14′ 9″ wide, 3′ 6″ deep, built on to very good brick masonry and concrete about 7′ 6″ deep, giving total thickness of 11′.

Result.—Clean hole through plate, and granite wall nearly disappeared. The large centre stone struck by shell was broken to small pieces, and the masonry wall in rear was split from top to bottom, the split in places being more than one foot wide, and extending to the rear, all the wall being much distorted.

The body of the shell seemed to have penetrated about 12″ into the masonry behind the granite, and it broke up very small, only 240 lbs. of fragments were recovered.

†Experiment on 11/5/77 with 64-pr. gun firing common shell of 64 lbs. and battering shell of 90 lbs., at velocities due to 12 lb. charge at about 1,000 yards, at masonry of extremely good quality. Experiments against masonry

1. Five battering shell were fired blind, weighted with sand.

---

* Proceedings of D. of A., 1878, p. 103.

† Proceedings of D. of A., 1878, p. 32.

Experiments against masonry.

2. Five battering shell were fired filled with powder (3·6 lbs.).
3. Six common shell were fired, filled and plugged.

General result of practice was—
(1.) These broke up on striking stone, but not on brickwork.
(2.) Two of these struck on iron and exploded.
One struck stone-work and exploded.
Two struck brickwork, one exploded, one blind.
(3.) All these exploded on striking stone or brickwork.

The battering shell appeared to be too soft, their points being destroyed by brickwork. The heads are now slightly chilled. The present shell fired with 12 lb. charge seems to be capable of perforating one 4″ unbacked iron plate at 1,000 yards.

Penetration in brickwork was from 2 to 3 feet. Further experiments on 10/10/77 with harder shells gave a penetration of 7 feet in brickwork.

Eastbourne experiments.

The result of experiments at Eastbourne in 1876 gives as penetration at 1,000 yards range, using 12 lb. charge,—

| | |
|---|---|
| Good masonry, common shell | - 3 to 5 feet. |
| „ battering „ | - 7 feet. |
| Concrete, common shell | - 4 feet. |

It has been found by experiment that common or battering shells when fired directly into masonry explode on impact, even when not fuzed. They would, therefore, as a rule be fired plugged, until the outer surface of the wall was destroyed, and then if there was a probability of the shells passing into earth in the rear, the Pettman or delay action fuzes would be used.*

## Against Earthworks.

Earthworks.

If it is required to damage the work common shell should be used. They will usually explode when fitted with a time fuze of the powder channel description, as this is driven into the shell and broken up on impact. The 20 sec. fuze cannot be depended upon for this.

A G.S. fuze should also explode when fired direct against a well made earthwork. The R.L. fuze is, however, more effective for this description of fire.

* Manual of R.A. Exercises, 1879, p. 24.

Earthworks.

One large shell will give a much greater effect than several small ones, and the earthwork should not be struck too low down, as in that case the earth which is thrown up is apt to fall back into its original place.

Effect of fire on a parapet.

The damaging effect of artillery fire on an earthen parapet are as follows:—

The crest is shot away, and the superior slopes receive indents and irregularities which interfere with the fire from the parapet. The exterior slope and upper portion of the escarp are shaken and covered with holes, which serve as foot holes to the assailant, the earth falling into the ditch and reducing its depth. Sharp angles and slopes finally disappear, and the parapet becomes a shapeless mass, and much earth collects at the foot of the escarp and banquette. The glacis is covered with furrows 3′ and 4′ long and about 1′ deep. The destruction of an earthwork does not practically go beyond certain limits, and the thickness at top would probably not be diminished more than a couple of feet, nor the crest reduced in general height more than a foot or 18 inches.

Penetration into earthworks.

The penetration into well-made earthworks with direct fire from rifled guns will be seen in the following table, taken from Handbook for Field Service (R.A.), and from the Drill Regulations for Prussian Artillery:—

| | Target and Gun. | Gun. | Projectile. | | | Striking Velocity. | Penetration. | Crater. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Weight. | If Shell Live or Blind. | Fuze. | | | Depth. | Breadth. | Height. |
| | | | Lbs. | | | | in. | | | |
| Prussian Regulations. | Sand | Lght. Field | 11·17 | Shell Blind | — | 1,286 | 39·4 | — | — | — |
| | Do. | Do. | Do. | Do. Live | F.S. Percⁿ | 1,286 | — | 20 | 59 | 59 |
| | Hard black earth | 15 C.M. Guns. | 60·3 | Do. Blind | — | 873 | 177 | — | — | — |
| | Fresh loam | | Do. | Do. do. | — | 839 | 197 | — | — | — |
| | Sandy soil | | 61 | Do. do. | — | 935 | 197 | — | — | — |
| | Do. | | Do. | Do. Live | F.S. Percⁿ | 935 | — | 39 | 59 | 59 |
| R. A. Handbk. | Compact loam | 7′ B.L. | 110 | Shot | — | At 1,000 yds. range. | 255 | — | — | — |
| | Do. | 40-pr. B.L. | 40 | Do. | — | | 175 | — | — | — |
| | Do. | 20-pr. B.L. | 20 | Do. | — | | 130 | — | — | — |
| | Do. | 12-pr. B.L. | 12 | Do. | — | | 48 | — | — | — |

At a range of 1,000 yards a parapet of earth 26′ thick was fired at by long 24 C.M. Krupp gun, charge 44 lbs., projectile common shell, weight 264 lbs., bursting charge 15 lbs., striking velocity 1,175 f.s. The parapet was cut through in two hits, the cut being $3\frac{1}{2}$′ deep, $10\frac{1}{2}$′ wide at exterior, and $8\frac{1}{2}$′ at interior crest.

Experiments against earthworks.

With same gun at same range it took 7 hits to cut through a similar parapet of sand. In this case the cut was 18′ broad and 4′ deep at exterior crest, sloping away to nothing at interior crest.

If the object is to injure the defenders, and the range is known, shrapnel shell with time fuze is probably the most effective projectile. This will be noticed under the next head.

## Against Boats or Bodies of Men Exposed.

### *With Shrapnel or Segment Shell.*

Boats or bodies of men exposed. Shrapnel.

Against boats or men exposed shrapnel shell should be used down to ranges at which case shot would be more effective, vide p. 265.

With time fuze.

From heavy guns time fuzes must be used with shrapnel, as the G.S. fuze cannot be relied on to burst on graze, and the R.L. fuze cannot at present be used.

The cone of dispersion of shrapnel fired from heavy guns is not known, but it is probable that it does not differ widely from that of shell fired from field guns, which is 8° to 9°.

Best effect.

Taking into consideration the angles of descent, this gives as the best results for the 9-pr. field gun, using time fuzes—

| | 1. Burst short of object. | 2. Front covered. |
|---|---|---|
| Under 1,000 yards range | 80 yards. | 11·2 yards. |
| From 1,000 to 2,000 yards range | 60 „ | 8·5 „ |
| „ 2,000 to 3,000 „ | 40 „ | 5·5 „ |
| Above 3,000 yards range | 30 „ | 4·2 „ |

The ricochet of the balls will, of course, increase this front. With heavy guns the figures in columns 1 and 2 would be considerably larger.

Height of burst and distance from object.

If the shell are burst close up, the front covered is smaller, and the bullets are much closer together.

When the burst is too far in front the effect is lessened, but this is better than bursting beyond the object, when the whole effect is lost.

As regards the height of the burst above the plane, the maximum effect is obtained when this height suits the distance.

At the same distance it is better to burst too low than too high, as the higher part of the cone is the more effective, and the lower part may ricochet. Height of burst and distance from object.

The angle of descent of the balls, at long ranges, gives shrapnel great searching power, but lessens the front covered.

Firing at short ranges the ricochet has considerable power, especially over water or hard ground. At long ranges, however, or over irregular or soft ground this effect is lost, and consequently the shell must be burst more accurately.

The report of a committee in 1869 gives the results of the trial of a large number of heavy shrapnel shell. Referring to 9″, 7″, and 64-pr. R.M.L. shrapnel it is stated, "The results of this practice afford conclusive evidence of the formidable nature of shrapnel shell. It is apparently most effective when burst 100 yards short of the target and 10 feet above the plane, but with the larger natures it is efficient even when burst 300 yards short of the object."

These distances would proportionately increase the length of front covered.

On this occasion some remarkably good practice was made. The shell were fired against three rows of targets 20 yards apart, each row having a frontage of 9 feet by 54 feet. The shells were not of the present pattern, but the following result is worth quoting, as showing the possible effect of a shrapnel shell fired under favourable conditions. A 9-inch shrapnel shell, weight 255 lbs., having 374 3 oz. balls and a bursting charge of 12 oz., was burst 136 yards short of the first target and 15·5 feet above the plane, the range to the first target being 1,200 yards. The total hits out of six rounds were 3,199, and of that number 3,038 went through the targets, the average number of hits per round being 533. This shows that many of the shot must have penetrated two targets, as the number of hits is considerably greater than the number of balls in the shell. By looking through the practice the enormous results obtained by a few rounds of shrapnel shell, properly directed, will be seen. Experiments with shrapnel.

On another occasion a 10″ shrapnel shell, containing 376 3 oz. sand shot, gave 646 hits on 3 rows of targets at a range of 1,050 yards; at 2,050 yards it gave 312 hits.

The 9 second fuze gives a limit of range of about 3,000 yards, but the use of the 15 second fuze will extend this to about 4,000.

From heavy guns shrapnel may be used up to these ranges when the distance is accurately known.

With percussion fuze.

With a percussion fuze, shrapnel after bursting on graze has (1) an ascending angle, and (2) a velocity considerably reduced. Where the ground is soft or irregular this is much increased, and the same is the case where the ground slopes towards the gun.

The following table shows the effect of field shrapnel burst on graze:—

| Range. | Angle of Ascent in Degrees. | Height of Lowest Bullets at | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 Yards. | 15 Yards. | 20 Yards. | 30 Yards. | 40 Yards. | 50 Yards. |
| | | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. |
| 1,000 | 2·5 | 1·4 | 2·1 | 2·8 | 4·2 | 5·5 | 6·9 |
| 2,000 | 8·0 | 4·0 | 5·9 | | | | |
| 3,000 | 14·2 | 6·8 | | | | | |

This shows how close up a shrapnel shell fitted with percussion fuze must be burst.

Judgment required.

The effect of shrapnel greatly depends on the correct estimate of the results that are being produced, and in most cases on the judgment displayed in the constant efforts to improve on the shooting; when used intelligently the effect is most excellent.

It is possible generally from the gun to estimate the line and the height of the burst of the shell, but not the distance at which it occurs, and bad practice commonly arises from a too sanguine estimate of effects judging from the appearance of the smoke of the burst alone; particular attention should, therefore, be paid to any visible marks of the bullet's grazing; on water splashes will be seen, and on dry ground puffs of dust, while on wet and boggy ground nothing may be seen.

It is often a good plan, where the range is not known, to fire a trial shot with a common shell, the burst of which is much more easily visible.

Segment shell.

From 20-pr. B.L. guns segment shell are used instead of shrapnel; they are very effective; but they require to be burst close in front of the object, as they scatter very much, and the segments do not long retain their velocity. The best results are obtained by using a percussion fuze and bursting the shell about 10 yards in front of the target.

They are effective up to the extreme range of the gun, if the distance is accurately known, but there is less margin for an error in this respect than with the shrapnel.

Segment shell would be very effective against troops behind a thin wall or against a torpedo boat.

*With Case Shot.*

When firing against boats or bodies of men exposed at short ranges, case shot would be used. Case shot.

As regards the most effective way of using case from heavy guns, no reliable data can be obtained. Heavy guns.

Experiments have at different times been carried out, but in many cases the results arrived at do not agree with each other. Different statements.

The Treatise on Ammunition states, p. 172, that with heavy guns—* Treatise on ammunition.

1. The best result is obtained by using double case and battering charges.
2. Case carries close, and is effective to 600 yards.
3. Firing over water, 1° of elevation should be given at 500 yards, and less for shorter ranges.

In 1877 case was fired from 12″·5 gun, charge 130 lbs., gun 17′ above plane, against a row of targets 54′ × 9′, range 600 yards, elevation 1°. Experiments with case.

Five rounds gave 210 hits, maximum range and spread seemed to be 1,500, and from 100 to 200 yards, while first graze was about 200 yards.

Using 80 lb. charge did not seem to increase the effect.

The hits on a section representing side of a torpedo boat 54′ × 3′ were on the average 14 per round, and on a target 7 feet square representing a section of the same, only 1 per round. It must be remembered that the case shot in this gun is nearly the full weight of projectile, and is rotated, having a gas-check.

In the proceedings of D. of A. for 1878, p. 236, it is stated that with heavy guns:— Proceedings of D. of A.

1. Fair results have been obtained with case shot from 9″ and 10″ guns up to 1,000 yards, using 3° elevation.
2. There are no reliable data, but experiments will be carried out, as case shot of the larger natures are very formidable at what may be called long ranges.

†These experiments were carried out with 10″ gun over water; battering charge and single case were used, and fired

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* D. of A., Vol. V., pp. 51, 137, 228. Double to 450 yards; Vol. VIII., p. 229; Vol. IX., p. 108. D. of A., 1877.
† D. of A., 1879.

Experiments with 10″ gun.

at elevations of 5°, 3°, 1°, P.B.; targets being at 500, 800, and 1,000 yards.

The gun used had been previously condemned for retubing, and this very possibly affected the results, which were very unsatisfactory; but showed as far as they went that:—

1. Absolutely no result was obtained on any target with 5° elevation.
2. Hardly any result was obtained on any target with 3° elevation.
3. Little result was obtained on any target with 1° elevation.
4. Fair results on all targets with P.B.

In the report of the experiment it is remarked that P.B. seems to be the best elevation, but that more experiments are required.

"Excellent" experiments.

As regards the use of single case shot fired from heavy guns with a full charge, the most reliable data are those given in the record of practice carried out in H.M.S. "Excellent," in 1874. Gun about 8′ above water. The following conclusions were arrived at:—

(1.) 10″ case gave excellent results up to 700 yards, and the greatest effect was obtained with the gun horizontal.

(2.) Results at 800 yards were satisfactory. Best elevation ½°.

(3.) Results at 900 yards were fair. Best elevation 1°.

(4.) At 900 yards a service cutter (condemned) broadside on was struck by the 10″ case (136 balls) with an average of five balls each round, and both sides of the boat were penetrated.

(5.) At 900 yards the greatest number of hits by one round of 10″ case on a target 100′ × 9′ was 37. Elevation 1°.

(6.) This range must be considered the limit. The balls had only just sufficient velocity to perforate the cutter.

(7.) 8″ (75 balls) and 9″ (113 balls) case at 900 yards only penetrated one side of the boat, and the number of hits was small. They cannot be considered effective at this range.

(8.) The first graze was in all cases under 100 yards, and the last fall was from 1,200 to 1,500 yards.

These results may be taken as a good guide when firing case under the above conditions, viz., single case and full charge.

As regards field and boats' guns, the Text Book on Ammunition, pp. 125, 210, states that case gives best effect at about 300 yards, and with 1° elevation. Field and boats' guns.

More should be given at longer ranges, increasing or decreasing ½° for each 100 yards, down to P.B. On soft ground this might be slightly increased.

Both with heavy and light guns, shrapnel, unplugged and entered fuze hole inwards, may on an emergency be used instead of case. It does not injure the gun, but the effect is very bad compared with case. The R.A. handbook for F.S. states that at 300 yards shrapnel fired from a field gun in this manner is nearly useless. Shrapnel fuze inwards.

## Curved and High-angle Fire.

### *Curved.*

This description of fire may be considered principally with reference to its effect on the deck of a ship. Curved fire.

As regards curved or depressed fire, experiments were carried out in 1872* by firing Palliser shell from 9″ and 10″ guns at a target representing the "Thunderer's" deck, the angle with the deck being 8° and 10°. Experiments.

The target representing the upper deck was composed of three thicknesses of 1″ iron plate covered by 4″ oak, and that representing the breastwork deck was two thicknesses of 1″ iron and 3½″ oak.

The gun was at 100 yards range, and battering charges were used. Experiments were also tried with 9″ flat-headed shell.

The Committee carrying out the experiments reported :—

Six projectiles (2 9″ and 4 10″), which struck fair on upper deck show that, though no actual perforation was obtained, considerable damage was done by the 10″ shells which burst (2), in one case large fragments of plating being driven down with great force.

Six projectiles (5 9″ and 1 10″) struck breastwork deck and all ricochetted, no actual perforation was obtained, but considerable damage was done, the iron broken and skin torn. Had these shell burst the effect would have been greater. No experiments were carried out with common shell. The upper

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* Proceedings D. of A., 1872.

deck may be considered proof against penetration by 10″ gun with battering charges up to angle of incidence of 10°.

The experimental flat-headed steel projectiles tried seemed not to be superior to the Palliser.

German experiments.

Similar experiments were carried out in Germany against a target representing a section of the "Konig Wilhelm's" deck, and consisting of 4″ plank on ½″ iron.

The gun used was the 15 C.M. (6-inch), weight of shell 61 lbs., at an angle of descent of 8° (due to a range of 3,281 yards), and a striking velocity 879 f. s., the target was proof, but was much damaged; while at a range of 3,718 yards, angle of descent 10½°, velocity 846 f. s., it was just perforated.

## *High-angle.*

High-angle fire.

It has been shown above that the decks of the newer classes of ships are fairly secure against a 10″ shell striking at an angle of 10°, but high angle fire from guns of moderate weight will penetrate any deck, and might inflict serious injuries on the engines, &c., although protected by shell gratings.

The magazines also are exposed to this danger, against which it is difficult to guard.

Where the distances are accurately mapped out, and the gun or mortar is mounted in a fort, very accurate practice may be made, and the only way in which an attacking ship could avoid serious injury would be by constant movement, and by avoiding as much as possible turning end on to the gun.

This latter point is very important, as with high angle fire the principal error is in range, and consequently the chance of striking a ship would be much greater when end on than when broadside on.

A great advantage of this system of fire against ships is that the gun being laid by means of pickets can be kept completely out of sight and protected against all fire except high angle.

Meppen experiments.

The recent (1879) trials at Meppen may be taken as an example of the accuracy attained by the rifled mortars and howitzers lately constructed.

The gun used was a 21 C.M. (8-inch) howitzer, weight 39½ cwt., length 6′ 9″, charge 16½ lbs., projectile 200 lbs.; and the mortar was a 15 C.M. (6-inch), weight 800 lbs., charge 2 lbs., projectile 69·3 lbs.

Thirteen rounds were fired from each, with the following results:— Meppen experiments.

| — | 8-in. Howitzer. | 6-in. Mortar. |
|---|---|---|
| Elevation | 18° 42′ | 45° |
| Mean range | 2,200 yards | 2,190 yards |
| Mean error in range | 28·7 " | 11·2 " |
| " " direction | 1· inch | 6·3 " |
| Greatest difference in range | 119 yards | 49 " |
| " " " direction | 6·6 " | 28 " |

A target was marked out representing the deck of a first-class ironclad, and all the rounds, except one from the mortar, fell within it.

Very good results have also been obtained by French and Austrian rifled mortars.

The new rifled howitzers lately constructed at Woolwich also give good results, but they are not S. S., and there is at present no mortar for either L. S. or S. S., except the old smooth bores.

The following experiment was carried out in Germany: German experiments.

The target represented the deck of the "Konig Wilhelm," and consisted of 4″ planks, with a ½″ iron skin supported by beams.

Mortar used was 21 C.M. (8-in.), shell weighing 177 lbs.

The following results were obtained: at range of 900 yards, angle of descent 30°, striking velocity 312 f. s., the shell penetrated with a delayed action fuze, but not with the ordinary fuze.

At higher ranges it penetrated easily.

When the deck was covered with 1″·93 chain cable in rows, it was proof against the same shell, with striking velocity of 312 f. s., up to an angle of descent of 57°, which was the largest used; but at 1,500 yards, striking velocity 400 f. s. it was perforated with an angle of descent of 30°, and it was found that there was no practical difference between laying the cable at right angles or parallel to the line of fire.

## Blank Firing.

As regards the effect of blank firing the following table gives the results of a trial of firing blank Charges of Service Pebble Powder at a Canvas Screen 40 ft. long and 6 ft. high:— Blank charges.

Effect of blank charges.

Gun was laid to centre of target.

| Rounds. | Gun. | Charge. | Elevation. | Distance of Target. | Remarks. |
|---|---|---|---|---|---|
| | Inch. | Lbs. | | Yds. | |
| 1 | 9 | 50 | 2 | 200 | No effect. |
| 2 | 9 | 50 | $1\frac{3}{4}$ | 100 | No effect. |
| 3 | 9 | 50 | 1 | 60 | Canvas hit hard by many pieces: one nearly through. |
| 4 | 10 | 44 | $1\frac{1}{2}$ | 80 | No effect. |
| 5 | 10 | 44 | 1 | 60 | Canvas hit hard in many places, and pebbles charred the canvas. |
| 6 | 10 | 44 | $1\frac{3}{4}$ | 100 | A few pellets reached the screen, but without force. |

2. The pellets in all cases covered the water from 50 to 90 yards from the gun.

3. From this result it is considered that 150 yards would be quite a safe distance for Ships to fire blank towards each other.

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## British and Foreign Guns.

Since the first introduction of rifled guns, which speaking generally may be said to have taken place during the years immediately following the Crimean war, the armaments of nearly all countries have undergone repeated changes of more or less importance.

England.

England who began with the Lancaster cast-iron muzzle-loader in 1855, adopted the Armstrong wrought-iron breech-loader in 1859. The method of closing the breech of these guns did not prove successful, and discredited breech-loaders in this country, so that muzzle-loaders were again resorted to in 1864, built up, however, on the Armstrong principle. These guns have been greatly developed in size, and at present form the entire armament of the fleet, but will now probably give place to longer breech-loaders.

France.

France commenced with rifled muzzle-loading guns, but in 1864 adopted breech-loading, and has since adhered to the general form then introduced. The guns of 1864 pattern were of cast iron and hooped; those of 1870 were of cast-iron, hooped and lined with steel, while in the later patterns of 1875 steel has been used throughout (diagram p. 49.)

Germany has almost uninterruptedly adhered to steel guns loaded at the breech. Germany.

Austria at one time adopted Armstrong muzzle-loaders, but has now changed to Krupp breech-loaders, the Uchatius bronze steel being only applied to small guns. Austria.

Italy has adhered to Armstrong's system of construction, and with one exception, the 12 c.m., her guns are muzzle-loaders. A trial of breech-loaders is, however, now to be made. Italy.

Russia has adopted breech-loaders and either buys them from Krupp or makes them on his models. Russia.

The smaller European powers have almost universally introduced the Krupp breech-loader.

America adhered for many years to large smooth-bore guns, but has now commenced to convert them into muzzle-loading rifles on the Palliser system, and is also turning attention to breech-loading. America.

The diagrams (p. 272.) represent in a concise form the powers of the most prominent English and foreign guns. Diagrams.

The remaining velocities have been calculated for projectiles with ogival heads of 1½ diameters.

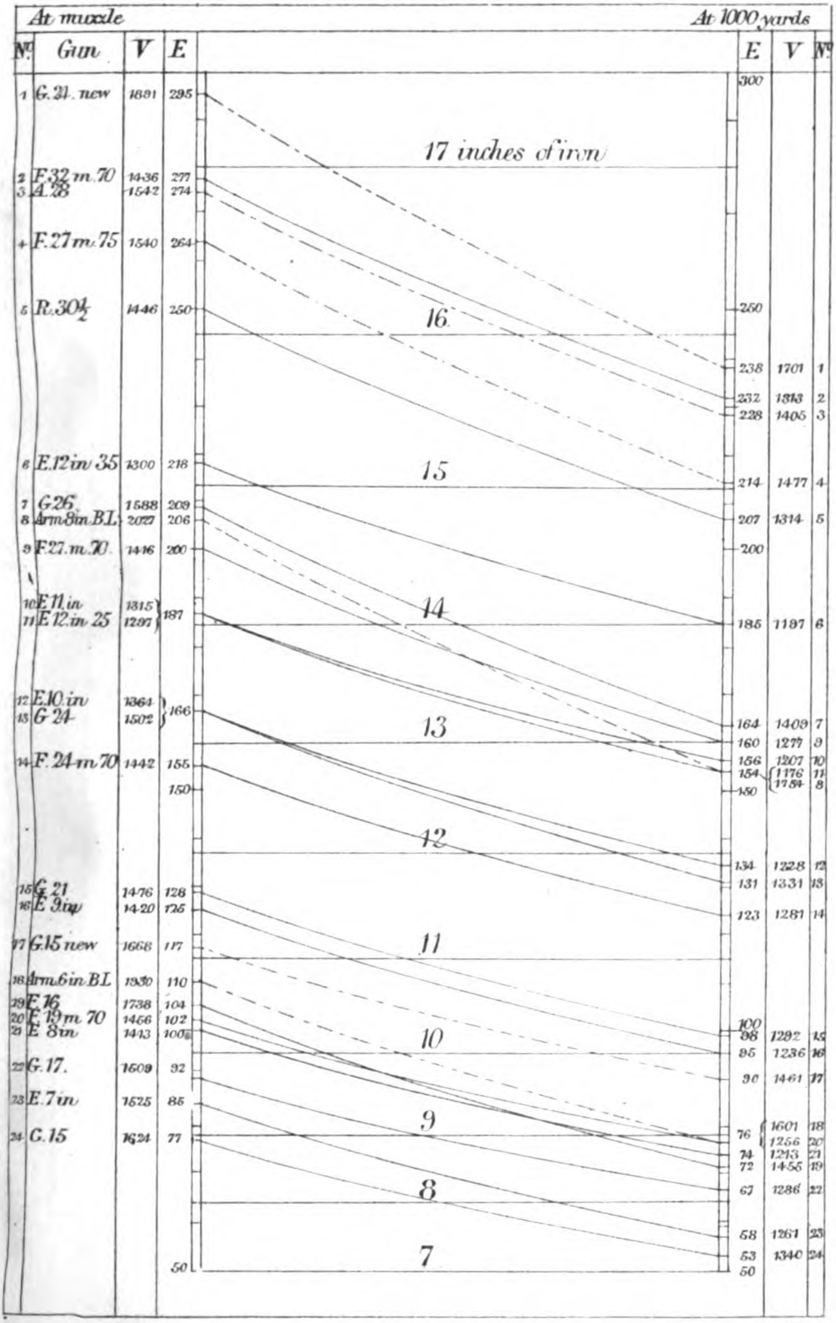
The heavy figures down the centre of the diagram refer to the thickness of solid unbacked wrought-iron plates, which can be perforated by projectiles with heads of 1½ diameters. Captain A. Noble's diagram (p. 244) has been used, and greater thicknesses than 17″ have not been inserted, owing to the difficulty of obtaining trustworthy data.

## Table showing the Particulars of Guns used in the Naval Service on the 1st January 1880.

| Nature and Nominal Weight. | Mark. | Preponderance. | Extreme Length. | Bore. Length in Inches. | Bore. Length in Cal. | Bore. Diameter. | Bore. Capacity, including Powder Chamber. | Rifling. Length. | Rifling. Grooves. System. | Rifling. Grooves. Number. | Rifling. Grooves. Width. | Rifling. Grooves. Depth. | Rifling. Twist. Nature. | Rifling. Twist. No. of Cal. in which 1 turn is taken at. | Rifling. Twist. Angle. | Angle of Tangent Sights for Permanent Deflection. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cwt. | ft. in. | | | in | c. in. | in. | | | in. | in. | | B. M. | B. M. | |
| 12''·5 of 38 ton - | I. | 0 | 19 2 | 198 | 15·8 | 12·5 | 24,578 | 170·5 | Wool. | 9 | 1·5 | ·2 | Increasing. | 0 35 | 0 5° 8′ | 2° 10′ |
| 12″ of 35 ton - | I. | 1½ | 16 3 | 162·5 | 13·5 | 12 | 18,586 | 135 | „ | 9 | 1·5 | ·2 | | 0 33 | 0 5° 8′ | 1° 25′ |
| 12″ of 25 ton - | I. | 6 | 15 3 | 145 | 12·0 | 12 | 16,692 | 127 | „ | 9 | 1·5 | ·2 | | 100 50 | 1° 48′, 3° 36′ | 0° 30′ |
| | II. | 0 | 15 2·5 | | | | 16,587 | | | | | | | 0 35 | 0 5° 8′ | 2° 26′ |
| 11″ of 25 ton - | I. | 2 | 15 2·5 | 145 | 13·2 | 11 | 13,981 | 119 | „ | 9 | 1·5 | ·2 | | | | |
| | II. | 1½ | 15 0 | | | | | | | | | | | 100 40 | 1° 48 4° 29′ | 1° 10′ |
| 10″ of 18 ton - | I. | 1½ | 15 0 | 145·5 | 14·5 | 10 | 11,589 | 118 | „ | 7 | 1·5 | ·2 | | | | |
| | II. | 1 | 15 0 | 145 | | | | | | | | | | | | |
| 9″ of 12 tons - | I. | 0 | 13 0 | 125 | 13·9 | 9 | 8,117 | 107·5 | „ | 6 | 1·5 | ·18 | | 0 45 | 0 4° | 0° 44 |
| | II., III., IV. | 5 | | | | | 8,062 | 104* | | | | | | | | |
| | V. | 3 | | | | | 8,062 | 104 | | | | | | | | |
| 8″ of 9 tons - | I. | 0 | 12 0 | 118 | 14·8 | 8 | 6,024 | 102 | „ | 4 | 1·5 | ·18 | | 0 40 | 0 4° 29′ | 0° 28′ |
| | II., III. | 4 | | | | | 5,987 | 99·5* | | | | | | | | |
| 7″ of 6½ tons - | I. | 5½ | 11 0 | 111 | 15·9 | 7 | 4,341 | 97·5 | „ | 3 | 1·5 | ·18 | Uniform. | 35 | 5° 8′ | 3° 0′ |
| | II., III. | 3 | 11 1 | | | | 4,314 | 95·5 | | | | | | 35 | 5° 8′ | 3° 0′ |
| 7″ of 90 cwt. - | I. | 5 | 10 11 | 111 | 15·9 | 7 | 4,314 | 95·5 | „ | 3 | 1·5 | ·18 | | | | |
| 64-pr. of 64 cwt. - | I. | 7 | 9 11·5 | 98 | 15·5 | 6·3 | 2,997 | 90·5 | Shunt or Plain† | 3 | ·6 / ·4 | ·11 / ·08 | | 40 | 4° 29′ | 2° 16′, 2° 16′, 2° 50 |
| | II. | 3 | 10 0 | 98 | | | 3,023 | | | 3 | ·6 | ·115 | | | | |
| | III. | 3½ | 9 10 | 98·5 | | | 3,040 | | | | | | | | | |
| 64-pr. of 71 cwt. - | — | 6½ | 10 2·7 | 103·27 | 16·4 | 6·29 | 3,196 | 96·27 | Plain. | 3 | ·6 | ·115 | | 40 | 4° 29′ | 2° 16′ |
| | | lbs. | | | | | | | | | | | | | | |
| 9-pr. of 8 cwt. - | II. | 7 | 6 0 | 63·5 | 21·3 | 3 | 459 | 59·8 | Modified French. | 3 | ·8 | ·11 | | 30 | 5° 59′ | 1° 30′ |
| 9-pr. of 6 cwt. - | I. | 3 | 5 1 | 53 | 17·6 | 3 | 383 | 49·3 | „ | 3 | ·8 | ·11 | | „ 20 | 8° „ 56′ | 3° „ 0′ |
| 7-pr. of 200 lbs., bronze | II. | 45 | 3 2½ | 32·15 | 11 | 3 | — | 29·15 | French. | 3 | ·6 | ·1 | | | | „ |
| 7-pr. of 200 lbs., steel | IV. | 5 | 3 5 | 36 | 12 | 3 | 261 | 34 | „ | „ | „ | „ | | „ 33 | 4° „ 44′ | — |
| 20-pr. B.L. of 13 cwt. | — | 164 | — | 53·09 | — | 3·75 | 627 | — | Poly. | 44 | ·166 | ·06 | | | | |

Those made before the 1st Jan. 1868 have the same rifling as Mark I.
All 64-prs. manufactured with steel tubes or those that have been re-tubed, whether with steel or iron, have the plain groove.

# ENERGY PER INCH OF CIRCUMFERENCE OF PROJECTILE IN FOOT TONS.




To face page 272

Dangerfield Lith 22 Bedford St. Covent Gar[den]

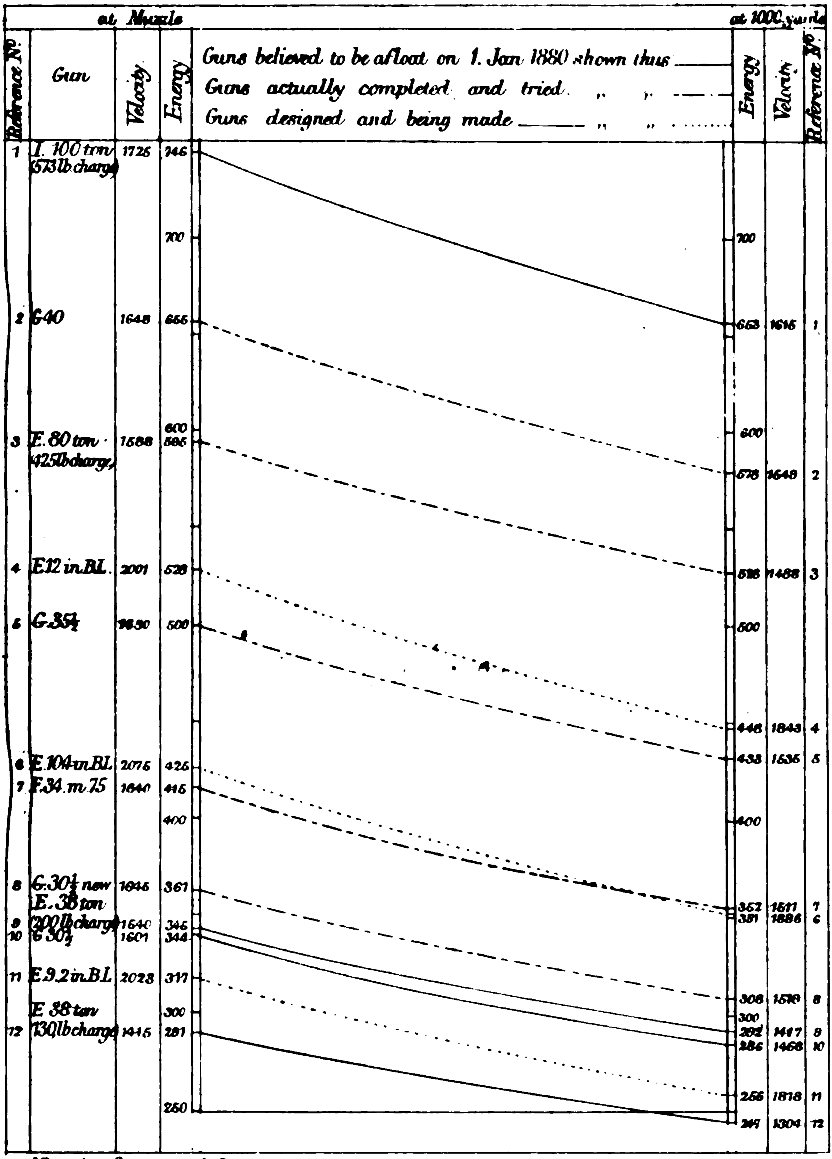
ENERGY

| Reference No. | Gun |
| --- | --- |
| 1 | E. 80 ton 450 lb charge |
| 2 | 440 |
| 3 | E. 80 ton 425 lb charge |
| 4 | E. 16 in B.L. |
| 5 | G. 35½ |
| 6 | E. 10.4 in B.L. 13½ in. 75 |
| 7 | G. 30½ new E. 38 ton 214 lb charge |
| 8 | E. 9.2 in B.L. |
| 9 | E. 38 ton 130 lb charge |

Note in ...
E. Eng...

To face p...

# ENERGY PER INCH OF CIRCUMFERENCE OF PROJECTILE. IN FOOT TONS.




Note in Column of Guns, figures refer to calibre in centimetres unless otherwise stated.
E. English. F. French. G. German. I. Italian. R. Russian. A. Austrian. Arm: Armstrong

To face page 272.

Dangerfield Lith. 22 Bedford St. Covent Garden.

**TABLE showing the Ballistic Power of Guns in use without Gas-checks in the Naval Service, 1st January 1880.**

| Nature and Nominal Weight. | Charge. | | | | | | Projectiles. | | | | Velocity. | | Energy in Foot Tons. | | | | | | Value of $\frac{w}{d^3}$ | Trajectory for Range. | | | Accuracy at 1,00 Yards. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | At Muzzle. | | | | At 1,000 Yards. | | | 600 Yards | 1,000 Yards. | | Size of Vertical Target to contain 25°/o hits. | |
| | Powder. | Weight. | Cub. in per lb. | Number of Expansions. | Maximum Pressure. | Mean Pressure in Powder Chamber. | Description. | Diameter. | Weight filled. | Burster. | Muzzle. | At 1,000 Yards. | Total. | Per ton of Gun. | Per lb. of Powder. | Per ton Maximum of Pressure. | Total. | Per Inch of Circumference. | | Maximum Height above Gun and point aimed at. | Angle of Descent. | Dangerous Space. | Height. | Breadth. |
| | | lbs. | | | tons. | tons. | | in. | | lbs. oz. | f. s. | | | | | | | | | ‡ feet. | ‡ ° ′ | ‡ yards. | | |
| 12″·5 of 33 tons | P² | 130 | 24·6 | 6·7 | 22·7 | — | Chill. | 12·42 | 818* | 11 12 | 1,415 | 1,304 | 11,357 | 290 | 87 | 500 | 9,645 | 247 | ·427 | 6·9 | 1 34 | 240 | | |
| | P² | 100 | — | 8·7 | — | — | Com. | " | 825* | 27 0 | — | — | — | — | — | — | — | — | — | — | — | — | | |
| 12″ of 35 tons | P | 110 | — | 6·0 | — | — | Chill. | 11·92 | 698 | 9 14 | 1,300 | 1,197 | 8,177 | 237 | 74 | — | 6,935 | 185 | ·412 | 8·2 | 1 39 | 231 | | |
| | P | 85 | — | 7·9 | — | — | Com. | " | 614 | 40 0 | — | — | — | — | — | — | — | — | — | — | — | — | | |
| 12″ of 25 tons | P | 85 | — | 6·9 | 18 | — | Chill. | " | 600 | 14 0 | 1,297 | 1,176 | 6,907 | 280 | 82 | 388 | 5,754 | 154 | ·354 | 8·4 | 1 56 | 198 | | |
| | P | 55 | — | 10·7 | — | — | Com. | " | 497 | 37 12 | 1,142 | 1,039 | — | — | — | — | — | — | — | 10·6 | 2 29 | 154 | | |
| 11″ of 25 tons | P | 85 | — | 5·6 | — | — | Chill. | 10·92 | 536 | 6 7 | 1,315 | 1,201 | 6,427 | 257 | 76 | — | 5,361 | 156 | ·412 | 8·0 | 1 40 | 210 | | |
| | P | 60 | — | 8·4 | — | — | Com. | " | 536 | 29 12 | — | — | — | — | — | — | — | — | — | — | — | — | | |
| 10″ of 18 tons | P | 70 | — | 5·9 | 19 | — | Chill. | 9·92 | 400 | 6 14 | 1,364 | 1,228 | 5,160 | 287 | 74 | 271 | 4,185 | 134 | ·409 | 7·5 | 1 46 | 216 | | |
| | P | 44 | — | 9·3 | — | — | Com. | " | 398 | 20 4 | 1,125 | 1,038 | — | — | — | — | — | — | — | 10·8 | 2 32 | 151 | | |
| 9″ of 12 tons | P | 50 | — | 5·7 | — | — | Chill. | 8·92 | 250 | 5 8 | 1,420 | 1,236 | 3,496 | 291 | 70 | — | 2,648 | 94 | ·352 | 7·0 | 1 44 | 220 | | |
| | R.L.G. | 30 | — | 9·6 | — | — | Com. | " | 250 | 19 0 | 1,192 | 1,063 | — | — | — | — | — | — | — | 9·9 | 2 19 | 165 | | |
| 8″ of 9 tons | P. | 35 | — | 6·1 | — | — | Chill. | 7·92 | 180 | 4 8 | 1,413 | 1,213 | 2,492 | 277 | 71 | — | 1,837 | 74 | ·362 | 7·1 | 1 43 | 222 | | |
| | R.L.G. | 20 | — | 10·7 | — | — | Com. | " | 180 | 14 8 | 1,163 | 1,035 | — | — | — | — | — | — | — | 10·5 | 2 29 | 154 | | |
| 7″ of 6½ tons | P. | 30 | — | 5·1 | — | — | Chill. | 6·92 | 115 | 2 8 | 1,525 | 1,261 | 1,856 | 285 | 62 | — | 1,268 | 58 | ·347 | 6·3 | 1 34 | 244 | | |
| | R.L.G. | 14 | — | 11·0 | — | — | Com. | " | 115 | 8 12 | 1,230 | 1,057 | — | — | — | — | — | — | — | 9·6 | 2 18 | 166 | | |
| 7″ of 90 cwt. | P. | 22 | — | 7·1 | 11·9† | — | Chill. | " | 115 | 2 8 | 1,361 | 1,150 | 1,477 | 328 | 67 | — | 1,054 | 48 | — | 7·9 | 1 55 | 199 | | |
| | P. | 22 | — | 7·1 | 13·4† | — | Doub. | " | 160 | 10 12 | 1,161 | 1,048 | — | — | — | — | — | — | — | 10·5 | 2 24 | 159 | | |
| | R.L.G. | 14 | — | 11·0 | 22·7† | — | Com. | " | 115 | 8 12 | 1,230 | 1,057 | — | — | — | — | — | — | — | 9·6 | 2 18 | 166 | | |
| | " | 14 | — | 11·0 | 24·5† | — | Doub. | " | 160 | 10 12 | 1,033 | 966 | — | — | — | — | — | — | — | 13·0 | 2 51 | 124 | | |
| 64-pr. of 64 cwt. | " | 10 | — | 24·5 | — | — | Com. | 6·22 | 64 | 7 2 | 1,378 | 1,084 | — | — | — | — | — | — | — | 8·5 | 2 6 | 181 | | |
| | " | 8 | — | 18·7 | — | — | " | " | 64 | 7 2 | 1,252 | 1,016 | 696 | 217 | 87 | — | — | — | — | 9·6 | 2 30 | 153 | | |
| 64-pr. of 71 cwt. | " | 8 | — | 14·5 | — | — | " | 6·22 | 64 | 7 2 | 1,230 | 1,006 | 672 | 192 | 84 | — | — | — | — | 10·0 | 2 33 | 150 | | |
| 9-pr. of 8 cwt. | L.G. | 1¾ | — | 9·3 | — | — | " | 2·94 | 9 | 0 7¼ | 1,381 | 990 | 119 | 297 | 68 | — | — | — | — | — | — | — | | |
| 9-pr. of 6 cwt. | " | 1½ | — | 8·9 | — | — | " | " | 9 | 0 7½ | 1,234 | 935 | 95 | 316 | 63 | — | — | — | — | — | — | — | | |
| 7-pr. of 200 lbs. (bronze). | F.G. | [illegible] | — | — | — | — | " | " | 7¼ | 0 6¼ | 914 | 731 | 42 | 269 | 84 | — | — | — | — | — | — | — | | |
| | " | [illegible] | — | — | — | — | Doub. | " | 12 | 0 15 | — | — | — | — | — | — | — | — | — | — | — | — | | |
| 7-pr. of 200 lbs. (steel). | " | [illegible] | — | — | — | — | Com. | " | 7¼ | 0 6¼ | 968 | 785 | 47 | 526 | 63 | — | — | — | — | — | — | — | | |
| | " | [illegible] | — | — | — | — | Doub. | " | 12 | 0 15 | — | — | — | — | — | — | — | — | — | — | — | — | | |
| 20-pr. B.L. of 13 cwt. | R.L.G. | 2½ | — | 3·7 | — | — | Com. | 3·75 | 21½ | 1 2 | 1,000 | 884 | 750 | 150 | 60 | — | — | — | — | — | — | — | | |

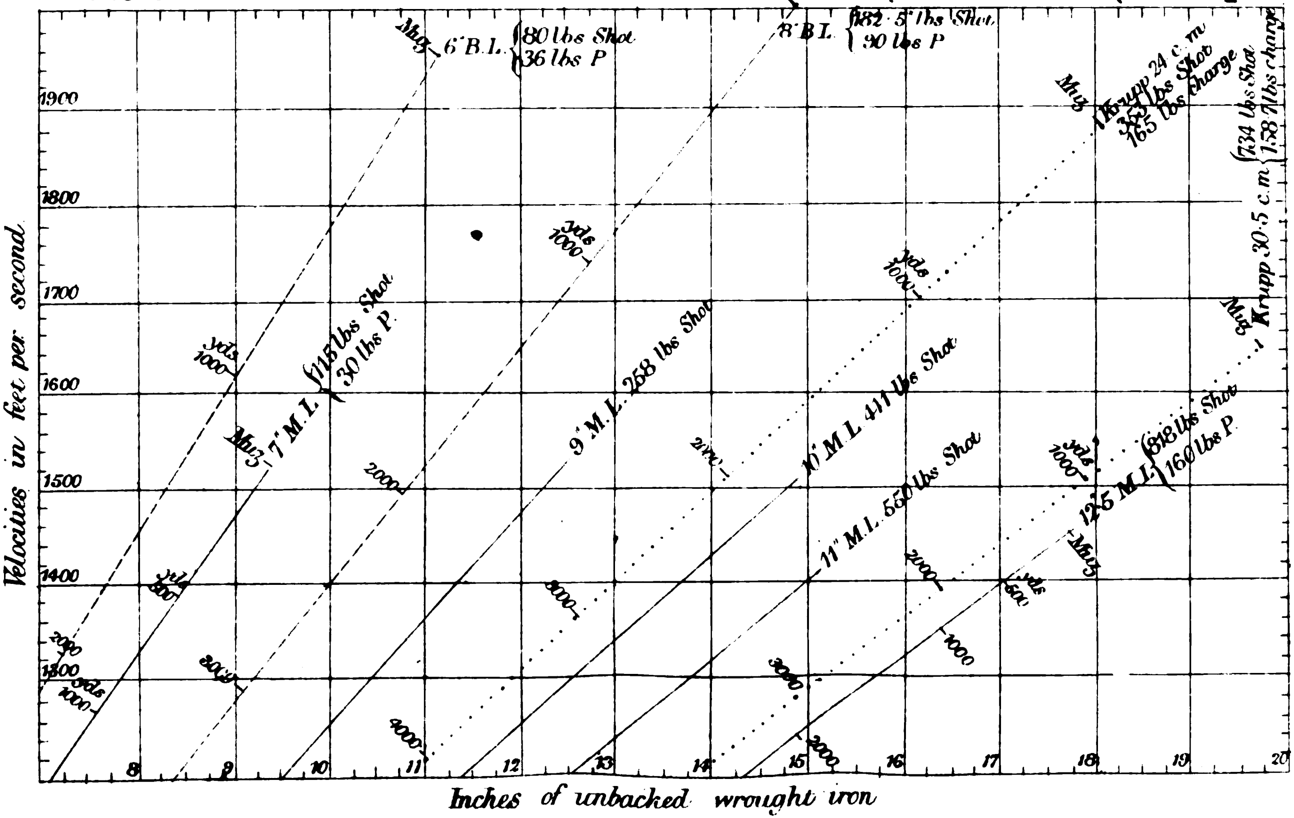
* With gas-check

TABLE showing the Ballistic Power which can be obtained with Gas-checks and suitable Powder.

| Nature and Nominal Weight. | Mark. | Charge. | | | | | | Projectiles with Gas-check. | | | | Velocity. | | Energy in Foot Tons. | | | | | | | Trajectory for a Range of | | | Accuracy at 1,000 Yards. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | At Muzzle. | | | | At 1,000 Yards. | | | 600 Yards | 1,000 Yards. | | Size of Vertical Target to contain 25% hits. | |
| | | Powder. | Weight. | Cub. in. per lb. | Number of Expansions. | Maximum Pressure. | Mean Pressure in Powder Chamber. | Description. | Diameter. | Weight filled. | Burster. | At Muzzle. | At 1,000 Yards. | Total. | Per ton of Gun. | Per lb. of Powder. | Per ton of Maximum Pressure. | Total. | Per Inch of Circumference. | Value of $\frac{w}{d^3}$ | Maximum Height above Gun and Object. | Angle of Descent. | Dangerous Space. | Height. | Breadth. |
| | | | lbs. | | | tons. | tons. | | in. | lbs. | lbs. oz. | | | | | | | | | | ‡ ft. | ‡ ° ' | ‡ | yds. | yds. |
| 12·5" of 38 tons | — | P² | 200 | 30 | — | 22 | 21 | Chill. | 12·42 | 818 | 11 12 | 1,540 | 1,417 | 13,452 | 354 | 67 | 611 | 11,389 | 291 | ·427 | 5·7 | 1 20 | | | |
| | — | P² | 160† | 30 | 5·44 | 22 | 21·6 | „ | „ | „ | „ | 1,445 | 1,306 | 11,843 | 311 | 74 | 538 | 9,900 | 253 | — | 6·6 | 1 29 | | | |
| 12" of 35 tons | — | P² | 140† | 28·9 | — | — | — | „ | 11·92 | 714 | 9 14 | 1,390 | 1,276 | 9,566 | 273 | 68 | — | 8,061 | 215 | ·422 | 7·1 | 1 38 | | ·36 | ·47 |
| | — | P | 110 | 25·9 | 6·09 | 25·6 | 22·0 | „ | „ | 711 | „ | 1,373 | 1,261 | 9,294 | 266 | 84 | 363 | 7,840 | 209 | — | 7·3 | 1 40 | | | |
| 12" of 25 tons | — | P² | 130 | 29 | 4·60 | 19·5* | 18·0 | „ | „ | 611 | 14 0 | 1,450 | 1,310 | 8,908 | 356 | 68 | — | 7,271 | 194 | ·363 | 6·6 | 1 32 | | | |
| | — | P | 85 | 26·7 | 7·04 | 20·8 | — | „ | „ | „ | „ | 1,293 | 1,177 | 7,083 | 283 | 83 | 340 | 5,869 | 156 | — | 8·4 | 1 54 | | | |
| 11" of 25 tons | — | P² | 115 | 28 | 4·39 | 21·5* | — | „ | 10·92 | 543 | 6 7 | 1,475 | 1,340 | 8,192 | 328 | 71 | — | 6,761 | 197 | ·418 | 6·4 | 1 28 | | | |
| | — | P | 85 | 26·8 | 5·93 | 22·0* | — | „ | „ | „ | „ | 1,350 | 1,231 | 6,862 | 274 | 80 | — | 5,706 | 166 | — | 7·5 | 1 45 | | | |
| 10" of 18 tons | — | P² | 100 | 27 | 4·15 | 22·4 | 20·7 | „ | 9·92 | 408 | 6 14 | 1,565 | 1,408 | 6,929 | 385 | 69 | 309 | 5,609 | 180 | ·420 | 5·6 | 1 19 | | | |
| | — | P | 70 | 25 | 5·87 | 22·1 | — | „ | „ | „ | „ | 1,433 | 1,291 | 5,810 | 323 | 83 | 263 | 4,715 | 151 | — | 6·6 | 1 34 | | | |
| 9" of 12 tons | — | P² | 75 | 27 | 3·92 | 21·7* | 18·4 | „ | 8·92 | 258 | 5 8 | 1,629 | 1,424 | 4,747 | 395 | 63 | — | 3,628 | 129 | ·363 | 5·3 | 1 16 | | | |
| | — | P | 50 | 26·6 | 5·74 | 18·2* | — | „ | „ | „ | „ | 1,458 | 1,276 | 3,803 | 317 | 76 | — | 2,913 | 104 | — | 6·6 | 1 35 | | | |

NOTE.—The charges of P² are the heaviest which it is proposed to use with the present guns. Their adoption would entail considerable changes in the mounting of the guns and of the magazine fittings.
* At end of bore. † Have been sealed for service. ‡ Approximate only.

# COL INGLIS' DIAGRAM FOR DIRECT PERFORATION OF UNBACKED WROUGHT IRON (HEADS 1½ DIAM)




To face page 275

Dangerfield, Lith. 22 Bedford St. Covent

TABLE showing the ENERGY of PROJECTILES fired with BATTERING CHARGES of P. POWDER from HEAVY RIFLED M.L. GUNS.

| Range. | 17·72 inch of 100 tons. Charge, lbs. Projectile, lbs. | | | | 16-inch of 80 tons. Charge, 425 lbs. $P^2$. Projectile, 1,700 lbs. | | | | 12·5-inch of 38 tons. Charge, 130 lbs. $P^2$. Projectile, 818 lbs. | | | | 12-inch of 35 tons. Charge, 110 lbs. P. Projectile, 700 lbs. | | | | 12-inch of 25 tons. Charge, 85 lbs, P. Projectile, 600 lbs. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *v.* | Total Energy. | Energy per Inch of Shot's Circumference | Unbacked Wrought Iron. | *v.* | Total Energy. | Energy per Inch of Shot's Circumference. | Unbacked Wrought Iron. | *v.* | Total Energy. | Energy per Inch of Shot's Circumference. | Unbacked Wrought Iron. | *v.* | Total Energy. | Energy per Inch of Shot's Circumference. | Unbacked Wrought Iron. | *v.* | Total Energy. | Energy per Inch of Shot's Circumference. | Unbacked Wrought Iron. |
| yards. | feet. | foot tons. | foot tons. | in. | feet. | foot tons. | foot tons. | in. | feet. | foot tons. | foot tons. | in. | feet. | foot tons. | foot tons. | in. | feet. | foot tons. | foot tons. | in. |
| 0 | — | — | — | — | 1,588 | 29,727 | 591 | — | 1,415 | 11,357 | 289 | 17·2 | 1,300 | 8,200 | 217 | 15·1 | 1,300 | 7,030 | 188 | 14·1 |
| 400 | — | — | — | — | 1,550 | 28,320 | 563 | — | 1,367 | 10,600 | 270 | 16·6 | 1,256 | 7,655 | 203 | 14·6 | 1,248 | 6,480 | 174 | 13·6 |
| 800 | — | — | — | — | 1,510 | 26,881 | 535 | — | 1,322 | 9,913 | 252 | 16·0 | 1,216 | 7,175 | 190 | 14·2 | 1,201 | 6,000 | 161 | 13·0 |
| 1,200 | — | — | — | — | 1,470 | 25,473 | 506 | — | 1,278 | 9,264 | 236 | 15·4 | 1,176 | 6,714 | 178 | 13·7 | 1,157 | 5,570 | 149 | 12·5 |
| 1,600 | — | — | — | — | 1,431 | 24,140 | 480 | — | 1,237 | 8,679 | 221 | 14·8 | 1,140 | 6,307 | 167 | 13·3 | 1,118 | 5,200 | 139 | 12·1 |
| 2,000 | — | — | — | — | 1,394 | 22,907 | 455 | — | 1,199 | 8,154 | 208 | 14·3 | 1,108 | 5,954 | 158 | 12·9 | 1,085 | 4,890 | 131 | 11·7 |
| — | 11-inch of 25 tons. Charge 85 lbs. P. Projectile, 535 lbs. | | | | 10-inch of 18 tons. Charge, 70 lbs. P. Projectile, 400 lbs. | | | | 9-inch of 12 tons. Charge, 50 lbs. P. Projectile, 250 lbs. | | | | 8-inch of 9 tons. Charge, 35 lbs. P. Projectile, 180 lbs. | | | | 7-inch of 6½ tons. Charge, 30 lbs. P. Projectile, 115 lbs. | | | |
| 0 | 1,315 | 6,415 | 187 | 13·9 | 1,864 | 5,160 | 166 | 13·1 | 1,420 | 3,496 | 124·7 | 11·5 | 1,41 | 2,492 | 100·2 | 10·3 | 1,525 | 1,855 | 85·3 | 9·4 |
| 400 | 1,265 | 5,935 | 173 | 13·3 | 1,308 | 4,745 | 152 | 12·6 | 1,341 | 3,117 | 111·2 | 10·8 | 1,327 | 2,198 | 88·3 | 9·7 | 1,409 | 1,583 | 72·8 | 8·6 |
| 800 | 1,220 | 5,520 | 161 | 12·8 | 1,254 | 4,360 | 140 | 12·0 | 1,270 | 2,796 | 99·8 | 10·2 | 1,248 | 1,944 | 78·1 | 9·1 | 1,317 | 1,383 | 63·6 | 7·9 |
| 1,200 | 1,179 | 5,155 | 150 | 12·3 | 1,204 | 4,020 | 129 | 11·4 | 1,204 | 2,513 | 89·7 | 9·6 | 1,180 | 1,738 | 69·9 | 8·5 | 1,217 | 1,181 | 54·3 | 7·3 |
| 1,600 | 1,139 | | 140 | 11·8 | 159 | 3,725 | 120 | 10·9 | 1,147 | 81 | 81·4 | 9·1 | 1,122 | 1,571 | 63·2 | 8·0 | 1,141 | 1,038 | 47·8 | 6·7 |
| 2,000 | 1,106 | 4,815<br>4,540 | 132 | 11·4 | 1,118 | 3,470 | 111 | 10·5 | 1,097 | 2,086 | 74·4 | 8·6 | 1,074 | 1.440 | 57·9 | 7·5 | 1,078 | 927 | 42·6 | 6·3 |

TABLE showing the Particulars of Experimental M.L. and proposed B.L. Guns.

| Nature and Nominal Weight. | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | Bore. | | | | Chamber. | | | Rifling. | | | | | | | | | Angle of Tangent Sights for Permanent Deflection. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length in Inches. | Length in Cal. | Diameter. | Capacity, including Powder Chamber. | Diameter. | Length. | Capacity. | Length. | Grooves. | | | | Lands | Twist. | | | |
| | | | | | | | | | | | | System. | Number. | Width. | Depth. | Width. | Nature. | No. of Cal. in which 1 turn is taken at. | Angle. | |
| *M.L.* | | | ft. in. | | | in. | c. in. | in. | in. | c. in. | in. | | | in. | in. | in. | | B. M. | B. M. | |
| 16″ of 80 tons | — | Nil. | 26 9 | 288 | 18 | 16·0 | 61,071 | 18·0 | 59·6 | 14,600 | 227·4 | Poly. | 33 | 1·0 | ·1 | ·523 | In. | 0 50 | 0 3° 38′ | |
| 8″ of 70 cwt. (Howitzer.) | — | — | 9 5 | 96 | 12 | 8·0 | — | 8·0 | 8·0 | 397 | 93·5 | „ | 24 | ·7 | {·05 ·10} | — | — | 100 35 | 1°48′5°8′ | |
| *B.L.* | | | | | | | | | | | | | | | | | | | | |
| 12″ of 43 tons | — | Nil. | 27 9 | 312 | 26 | 12·0 | 39,057 | 15·5 | 58·35 | 10,120 | — | — | — | — | — | — | — | — | — | |
| 10″·4 of 26 tons | — | Nil. | 24 5 | 276 | 26·5 | 10·4 | 26,103 | 12·8 | 63·20 | 7,854 | — | — | — | — | — | — | — | — | — | |
| 9″·2 of 18 tons | — | Nil. | 21 8 | 244·5 | 26·6 | 9·2 | 18,094 | 11·3 | 56·30 | 5,440 | — | — | — | — | — | — | — | — | — | |
| 6″ of 78 cwt. | — | Nil. | 12 2 | 138·0 | 23 | 6 | 4,356 | 8·08 | 22·14 | 1,040 | 116·1 | -- | 16 | — | — | — | — | 90 38 | 2°0′4°44 | |
| 25 pr. of 22¼ cwt. | — | Nil. | 8 11 | 100·0 | 25 | 4 | 1,50 | 5·3 | 20·50 | 432 | — | — | — | — | — | — | — | — | — | |

TABLE showing the probable Ballistic Power of Experimental M.L. and proposed B.L. Guns.

| Nature and Nominal Weight. | Charge. | | | | | | Projectile. | | | | Velocity. | | Energy in Foot Tons. | | | | | | Value of $\frac{w}{d^2}$. | Trajectory for Range. | | | Accuracy 1,000 yds. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | At Muzzle. | | | | At 1,000 Yards. | | | 600 Yards. | 1,000 Yards. | | Size of Vertical Target to contain 25 % hits. | |
| | Powder. | Weight. | Cubic Inches per lb. | Number of Expansions. | Maximum Pressure. | Mean Pressure in Powder Chamber. | Description. | Diameter. | Weight filled. | Burster. | Muzzle. | At 1,000 Yards. | Total. | Per ton of Gun. | Per lb. of Powder. | Per ton of Maximum Pressure. | Total. | Per inch of Circumference. | | Maximum Height above Gun and point aimed at. | Angle of Descent. | Dangerous Space. | Height. | Breadth. |
| *M.L.* | | lbs. | | | | | | in. | lbs. | lbs. | f. s. | f. s. | | | | | | | | ‡ ft. | ‡ ° ′ | ‡ Yds | Yds. | Yds |
| 16″ of 80 tons | P² | 425 " | 34 " | 5·19 | 25 | — | Chill. Com. | 15·92 " | 1703 " | 17·5 57·7 | 1,588 | 1,48 | 29,663 | 371 | 70 | 1,186 | 26,147 | 523 | ·421 | 5·3 | 1 13 | 314 | — | — |
| 8″ of 70 cwt. (Howitzer.) | R.L.G.² | 11½ | — | — | — | — | Com. | — | 180 | — | 956 | 888 | — | — | — | — | — | — | — | — | 3 21 | — | ·65 | ·32 |
| *B.L.* 12″ of 43 tons | P² | 285 | 35·5 | 4·942 | — | 16·4 | — | 11·94 | 714 | ? | 2,001 | 1,843 | 19,820 | 461 | 70 | — | 16,810 | 448 | ·420 | 3·5 | 0 47 | Whole range. | — | — |
| 10″·4 of 26 tons | P² | 231 | 34·0 | 4·074 | — | 17·5 | — | 10·34 | 462 | ? | 2,075 | 1,886 | 13,778 | 530 | 60 | — | 11,395 | 351 | ·418 | 3·3 | 0 44 | | — | — |
| 9″·2 of 18 tons | P² | 160 | 34·0 | 4·078 | — | 17·5 | — | 9·14 | 320 | ? | 2,025 | 1,818 | 9,096 | 505 | 57 | — | 7,334 | 255 | ·419 | 3·4 | 0 47 | | — | — |
| 6″ of 78 cwt. | P | 34 | 30·6 | 4·62 | — | 13·8 | — | 5·97 | 69 | — | 2,009 | 1,620 | 1,931 | 495 | 57 | — | 1,256 | 67 | ·376 | 3·7 | 0 57 | 540 | — | — |
| 25 pr. of 22½ cwt | R.L. 9.² | 12 | 36 | 4·522 | — | 13·0 | Com | — | 25 | — | 1,876 | 1,438 | 610 | 542 | — | — | 358 | 29 | | | | | | |

‡ Approximate only.

TABLE showing the Particulars of French Naval B.L. Guns.

| Nature and Nominal Weight. | | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | Bore. Length in Inches. | Bore. Length in Calibres. | Bore. Diameter. | Bore. Capacity, including Powder Chamber. | Chamber. Diameter. | Chamber. Length. | Chamber. Capacity. | Rifling. Length. | Rifling. Grooves. System. | Rifling. Grooves. Number.* | Rifling. Grooves. Width. | Rifling. Grooves. Depth. | Rifling. Lands. Width. | Rifling. Twist. Nature. | Twist. No. of Calibres in which One Turn is taken at. B. | Twist. No. of Calibres in which One Turn is taken at. M. | Twist. Angle. B. | Twist. Angle. M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cwt. | cwt. | ft. in. | | | in. | | | | | | | | | in. | | | | | | |
| 42 c.m. of 72 tons | Pattern 1875. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| 34 c.m. of 46 tons | Pattern 1875. | 16¾ | 15¾ | 22 0 | 241 | 18·0 | 13·38 | — | — | — | — | — | — | 68 | — | ·058 | — | | — | — | — | — |
| 27 c.m. of 27¾ tons | Pattern 1875. | 9⅞ | 8½ | 19 3 | 213 | 19·8 | 10·80 | — | — | — | — | — | — | 54 | — | ·058 | — | | — | — | — | — |
| 27 c.m. of 24¾ tons | Pattern 1875. | 9⅞ | 9½ | 19 3 | 213 | 19·8 | 10·80 | — | — | — | — | — | — | 42 | — | ·058 | — | | — | — | — | — |
| 10 c.m. of 24 cwt. | Pattern 1875. | ¾ | 2 | 9 3 | 90 | 26·0 | 3·94 | — | — | — | — | — | — | 20 | — | ·031 | — | | — | — | — | — |
| 32 c.m. of 38½ tons | Pattern 1870. | 13¾ | 3¼ | 22 0 | 244 | 19·3 | 12·60 | — | — | — | — | — | — | 32 | — | ·058 | — | Increasing. | 0 | 45 | 0 | 4° |
| 32 c.m. of 34½ tons | Pattern 1870. | 13¾ | 9½ | 18 9 | 205 | 16·2 | 12·60 | — | — | — | — | — | — | — | — | ·058 | — | Increasing. | — | — | — | — |
| 27 c.m. of 23 tons | Pattern 1870. | 9⅞ | 7¼ | 17 8 | 194 | 18·0 | 10·80 | — | — | — | — | — | — | 28 | — | ·058 | — | Increasing. | 0 | 45 | 0 | 4° |
| 24 c.m. of 15½ tons | Pattern 1870. | 6¼ | 5⅞ | 16 2 | 180 | 19·0 | 9·45 | — | — | — | — | — | — | 24 | — | ·058 | — | Increasing. | 0 | 45 | 0 | 4° |
| 19 c.m. of 7¾ tons | Pattern 1870. | 3½ | 2½ | 13 7 | 163 | 19·7 | 7·64 | — | — | — | — | — | — | 20 | — | ·058 | — | Increasing. | 0 | 45 | 0 | 4° |
| 19 c.m. of 7½ tons | Pattern 1870. | 3¼ | 2½ | 12 5 | 137 | 18·0 | 7·64 | — | — | — | — | — | — | 20 | — | ·058 | — | Increasing. | — | — | — | — |
| 16 c.m. of 5 tons | Pattern 1870. | 2¼ | 2 | 12 2 | 136 | 21·0 | 6·48 | — | — | — | — | — | — | 16 | — | ·058 | — | Increasing. | 0 | 30 | 0 | 5° 59′ |
| 14 c.m. of 53 cwt. | Pattern 1870. | 1 9/16 | 1 | 10 3 | 115 | 21·0 | 5·45 | — | — | — | — | — | — | 14 | — | ·047 | — | Increasing. | 0 | 30 | 0 | 5° 59 |

TABLE showing the Ballistic Power of French Naval Guns.

| Nature and Nominal Weight. | Charge. Powder. | Charge. Weight. | Charge. Cubic Inches per lb.* | Charge. Number of Expansions. | Charge. Maximum Pressure. | Charge. Mean Pressure. | Projectile. Description. | Projectile. Diameter. | Projectile. Total Weight. | Projectile. Burster. | Velocity. Muzzle. | Velocity. At 1,000 Yards. | Energy in foot tons. At Muzzle. Total. | At Muzzle. Per ton Weight of Gun. | At Muzzle. Per lb. of Powder. | At Muzzle. Per ton of Pressure. | At 1,000 Yards. Total. | At 1,000 Yards. Per Inch of Circumference. | Value of $\frac{w}{d^3}$. | Trajectory for Range of 600 Yards. Maximum Height above Gun and point aimed at. | Trajectory 1,000 Yards. Angle of Descent. | Trajectory 1,000 Yards. Dangerous Space. | Accuracy at 1,000 Yards. Size of Horizontal Target to contain 25 per cent. hits. Length. | Breadth. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | lbs. | | | | | | in. | lbs. | lbs. | f. s. | f. s. | | | | | | | | | | yds. | yds. | yds. |
| 42 c.m. of 72 tons | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 34 c.m. of 46 tons | — | 278 | — | — | — | — | Steel | 13·26 | 927 | 14·8 | 1,640 | 1,511 | 17,291 | 376 | 62 | — | 14,676 | 352 | 398 | — | — | — | — | — |
| | | ″ | — | — | — | — | Com. | ″ | 782 | 42·6 | (?) | | — | — | — | — | — | — | — | — | — | — | — | — |
| 27 c.m. of 27¾ tons | — | 136 | — | — | — | — | Steel | 10·70 | 476 | 5·7 | 1,640 | 1,477 | 8,878 | 324 | 67 | — | 7,201 | 214 | 389 | — | — | — | — | — |
| | | 121 | — | — | — | — | Com. | ″ | 397 | 24·1 | 1,656 | 1,461 | — | — | — | — | — | — | — | — | — | — | — | — |
| 27 c.m. of 24¾ tons | W.* 0″·8 | 104 | — | — | — | — | Steel | ″ | 476 | 5·7 | 1,542 | 1,387 | 7,848 | 322 | 75 | — | 6,350 | 189 | 380 | — | — | — | — | — |
| | to 1″ | ″ | — | — | — | — | Com. | ″ | 397 | 24·1 | 1,656 | 1,461 | — | — | — | — | — | — | — | — | — | — | — | — |
| 10 c.m. of 24 cwt. | W.0″·5 to 0″·6 | 6·8 | — | — | — | — | Com. | 3·86 | 25·4 | 1·3 | 1,591 | 1,235 | — | — | — | — | — | — | — | — | — | — | — | — |
| 32 c.m. of 38½ tons | W.1″ | 151 | — | — | — | — | Steel | 12·48 | 761 | 11·4 | 1,436 | 1,313 | 10,881 | 282 | 72 | — | 9,097 | 232 | 391 | — | — | — | — | — |
| | to 1″·2 | ″ | — | — | — | — | Com. | ″ | 631 | 37·5 | 1,558 | 1,398 | — | — | — | — | — | — | — | — | — | — | — | — |
| 32 c.m. of 34¼ tons | Do. | 148 | — | — | — | — | Steel | ″ | 761 | 11·4 | 1,384 | 1,268 | 10,107 | 292 | 68 | — | 8,484 | 216 | 391 | — | — | — | — | — |
| | ″ | ″ | — | — | — | — | Com. | ″ | 631 | 37·5 | 1,489 | 1,336 | — | — | — | — | — | — | — | — | — | — | — | — |
| 27 c.m. of 23 tons | W.0″·8 | 92·6 | — | — | — | — | Steel | 10·70 | 476 | — | 1,416 | 1,277 | 6,616 | 289 | 71·4 | — | 5,381 | 160 | 380 | — | — | — | — | — |
| | to 1″ | ″ | — | — | — | — | Com. | ″ | 397 | 24 | 1,542 | 1,360 | — | — | — | — | — | — | — | — | — | — | 34·0 | 0·77 |
| 24 c.m. of 15¾ tons | W.0″·5 | 61·8 | — | — | — | — | Steel | 9·35 | 317 | — | 1,442 | 1,281 | 4,569 | 297 | 74 | — | 3,606 | 123 | 388 | — | — | — | — | — |
| | to 0″·6 | ″ | — | — | — | — | Com. | ″ | 265 | 17·7 | 1,555 | 1,347 | — | — | — | — | — | — | — | — | — | — | 29·3 | 0·66 |
| 19 c.m. of 7¾ tons | Do. | 33·0 | — | — | — | — | Steel | 7·54 | 165 | 2·9 | 1,456 | 1,256 | 2,425 | 308 | 73·5 | — | 1,804 | 76 | 385 | — | — | — | — | — |
| | ″ | ″ | — | — | — | — | Com. | ″ | 138 | 7·4 | 1,591 | 1,329 | — | — | — | — | — | — | — | — | — | — | — | — |
| 19 c.m. of 7½ tons | Do. | ″ | — | — | — | — | Steel | ″ | 165 | 2·9 | 1,456 | 1,256 | 2,425 | 308 | 73·5 | — | 1,804 | 76 | 385 | — | — | — | — | — |
| | | ″ | — | — | — | — | Com. | ″ | 115 | 4·7 | 1,694 | 1,370 | — | — | — | — | — | — | — | — | — | — | — | — |
| 16 c.m. of 5 tons | Do. | 38·6 | — | — | — | — | Steel | 6·38 | 99 | 1·6 | 1,738 | 1,455 | 2,074 | 415 | 54 | — | 1,453 | 72 | 381 | — | — | — | — | — |
| | | ? | — | — | — | — | Com. | ″ | 99 | 5·5 | (?) | | — | — | — | — | — | — | — | — | — | — | — | — |
| 14 c.m. of 53 cwt. | W.0″·5 to 0″·6 | 9·0 | — | — | — | — | Com. | 5·37 | 46 | 2·4 | 1,493 | 1,151 | — | — | — | — | — | — | — | — | — | — | 30·6 | 0·9 |

* W. means Wetteren and the numbers refer to the size of the grain.

## TABLE showing the Particulars of German Naval Guns.

| Nature and Nominal Weight. | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | Bore. Length in Inches. | Bore. Length in Calibres. | Bore. Diameter. | Bore. Capacity, including Powder Chamber. | Chamber. Diameter. | Chamber. Length. | Chamber. Capacity. | Rifling. Length. | Rifling. Grooves. System. | Grooves. Number. | Grooves. Width at Muzzle. | Grooves. Depth. | Lands. Width. | Twist. Nature. | Twist. No. of Calibres in which 1 turn is taken. | Twist. Angle. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cwt. | lbs. | ft. in. | | | in. | | | in. | | in. | | | in. | in. | in. | | B. M. | ° ′ |
| 30·5 c.m. of 36 tons | 26½ | Nil. | 22 0 | 226·4 | 18·8 | 12·01 | — | — | 54·6 | — | 171·8 | Wedge | 72 | — | — | — | Uniform. | 45 | 4 0 |
| 26 c.m. of 22½ tons | 18 | ” | 18 9 | 194·6 | 18·8 | 10·32 | — | — | 55·3 | — | 139·3 | Parallel | 36 | ·705 | ·077 | — | Uniform. | 50 | 3 36 |
| 26 c.m. of 18½ tons | 18 | ” | 17 1 | 169·9 | 16·6 | 10·24 | — | — | 42·1 | — | 127·8 | ” | 36 | ·705 | ·126 | — | Uniform. | 50 | 3 36 |
| 24 c.m. of 15½ tons | 12¼ | ” | 17 2 | 174·1 | 18·7 | 9·27 | — | — | 38·3 | — | 135·8 | Wedge | 32 | ·689 | ·112 | — | Uniform. | 70 | 2 34 |
| 24 c.m. of 14½ tons | 12¼ | ” | 15 5 | 153·6 | 16·5 | 9·27 | — | — | 38·2 | — | 115·4 | ” | 32 | ·689 | ·112 | — | Uniform. | 63 | 2 46 |
| 21 c.m. of 10 tons | 7¾ | ” | 15 5 | 158·2 | 19·0 | 8·23 | — | — | 33·7 | — | 124·5 | ” | 30 | ·575 | ·102 | — | Uniform. | 68 | 2 38 |
| 21 c.m. of 9½ tons | 7¾ | ” | 12 10 | 128·1 | 15·5 | 8·23 | — | — | 31·4 | — | 96·8 | ” | 30 | ·575 | ·102 | — | Uniform. | 59 | 3 3 |
| 17 c.m. of 5¾ tons | 4¾ | ” | 14 0 | 146·3 | 21·5 | 6·79 | — | — | 40·8 | — | 105·5 | ” | 30 | ·453 | ·063 | — | Uniform. | 45 | 4 0 |
| 17 c.m. of 5 tons | 4¾ | ” | 11 2 | 116·6 | 17·1 | 6·79 | — | — | 24·7 | — | 91·9 | ” | 30 | ·472 | ·063 | — | Uniform. | 59 | 3 3 |
| 17 c.m. of 72 cwt. | 3¾ | ” | 11 4 | 118·3 | 17·4 | 6·79 | — | — | 25·7 | — | 92·6 | Parallel | 30 | ·327 | ·063 | — | In. | 0 to 45 | 0 to 4° |
| 15 c.m. of 81 cwt. | 2¼ | 155 | 12 8 | 132·6 | 22·7 | 5·87 | — | — | 26·9 | — | 105·7 | Wedge | 24 | ·512 | ·061 | — | Uniform. | 45 | 4 0 |
| 15 c.m. of 72 cwt. | 2¼ | 441 | 10 9 | 110·2 | 18·9 | 5·87 | — | — | 23·5 | — | 86·7 | ” | 24 | ·512 | ·061 | — | Uniform. | 68 | 2 38 |
| 15 c.m. of 66 cwt. | 3¾ | 618 | 10 8 | 110·2 | 18·9 | 5·87 | — | — | 23·5 | — | 86·7 | ” | 24 | ·512 | ·061 | — | Uniform. | 65 | 2 46 |
| 12·5 c.m. of 29 cwt. | 1½ | 221 | 9 7 | 107·5 | 21·8 | 4·92 | — | — | 21·8 | — | 85·7 | ” | 32 | — | — | — | In. | 0 to 45 | 0 to 4° |
| 12 c.m. of 29 cwt. | 1½ | 221 | 9 7 | 100·4 | 21·2 | 4·73 | — | — | 14·7 | — | 85·7 | ” | 18 | ·512 | ·051 | — | Uniform. | 60 | 3 0 |
| | lbs. | | | | | | | | | | | | | | | | | | |
| 8 c.m. of 7 cwt. | 64 | 155 | 6 4 | 66·0 | 21·3 | 3·09 | — | — | 8·4 | — | 57·6 | ” | 12 | ·551 | ·049 | — | Uniform. | 46 | 3 54 |
| 8 c.m. of 6¼ cwt. | 64 | 155 | 6 4 | 66·0 | 21·3 | 3·09 | — | — | 8·4 | — | 57·6 | ” | 12 | ·551 | ·049 | — | Uniform. | 46 | 3 54 |
| 8 c.m. of 4½ cwt. | 55 | 155 | 5 2 | 53·5 | 16·7 | 3·19 | — | — | 7·7 | — | 45·8 | ” | 12 | ·581 | ·051 | — | Uniform. | 46 | 3 54 |
| 4 c.m. of 160 lbs. | 15 | Nil. | 5 9 | 63·6 | 41·3 | 1·54 | — | — | 9·0 | — | 54·6 | ” | 12 | — | — | — | Uniform. | 0 to 70 | 0 to 2° 34′ |

TABLE showing the Ballistic Power of German Naval Guns.

| Nature and Nominal Weight. | Charges. Powder. | Charges. Weight. | Charges. Cubic in. per lb. | Charges. Number of Expansions. | Charges. Maximum Pressure. | Charges. Mean Pressure in Powder Chamber. | Projectiles. Description. | Projectiles. Diameter. | Projectiles. Total Weight filled. | Projectiles. Burster. | Velocity. Muzzle. | Velocity. At 1,000 Yards. | Energy in ft. tons. At Muzzle. Total. | Energy in ft. tons. At Muzzle. Per ton of Gun. | Energy in ft. tons. At Muzzle. Per lb. of Powder. | Energy in ft. tons. At Muzzle. Per ton of Maximum Pressure. | Energy in ft. tons. At 1,000 Yards. Total. | Energy in ft. tons. At 1,000 Yards. Per in. of Circumference. | Value of $\frac{w}{d^3}$. | Trajectory for Range of 600 Yards. Maximum Height above Gun and point aimed at. | Trajectory for Range of 1,000 Yards. Angle of Descent. | Trajectory for Range of 1,000 Yards. Dangerous Space. | Accuracy at 1,000 Yards. Size of Target to contain 25 per cent. Hits. Height. | Accuracy at 1,000 Yards. Size of Target to contain 25 per cent. Hits. Breadth. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | lbs. | | | | | | in. | lbs. | lbs. | | | | | | | | | | | | | | |
| 30·5 c.m. of 36 tons | — | 159 | — | — | — | — | Chill. | 11·93 | 717 | 8 | 1,601 | 1,468 | 12,903 | 358 | 80 | — | 10,715 | 286 | ·422 | | | | | |
| | — | „ | — | — | — | — | Com. | „ | 611 | 22 | 1,657 | 1,498 | — | — | — | — | — | — | — | | | | | |
| 26 c.m. of 22½ tons | — | 110 | — | — | — | — | Chill. | 10·24 | 384 | 5·3 | 1,588 | 1,409 | 6,715 | 298 | 61 | — | 5,236 | 164 | ·358 | | | | | |
| | — | „ | — | — | — | — | Com. | „ | 340 | 17·2 | 1,640 | 1,434 | — | — | — | — | — | — | — | | | | | |
| 26 c.m. of 18½ tons | — | „ | — | — | — | — | Chill. | „ | 384 | 5·3 | 1,542 | 1,367 | 6,831 | 281 | 57 | — | 4,979 | 155 | ·358 | | | | | |
| | — | „ | — | — | — | — | Com. | „ | 340 | 17·2 | 1,591 | 1,390 | — | — | — | — | — | — | — | | | | | |
| 24 c.m. of 15¼ tons | — | 59·5 | — | — | — | — | Chill. | 9·19 | 307 | 3·8 | 1,502 | 1,331 | 4,803 | 315 | 81 | — | 3,771 | 131 | ·396 | | | | | |
| | — | 44·1 | — | — | — | — | Com. | „ | 259 | 15·4 | 1,391 | 1,213 | — | — | — | — | — | — | — | | | | | |
| 24 c.m. of 14¼ tons | — | 59·5 | — | — | — | — | Chill. | „ | 307 | 3·8 | 1,469 | 1,303 | 4,594 | 316 | 77 | — | 3,614 | 125 | ·396 | | | | | |
| | — | 44·1 | — | — | — | — | Com. | „ | 259 | 15·4 | 1,355 | 1,184 | — | — | — | — | — | — | — | | | | | |
| 21 c.m. of 10 tons | — | 42·0 | — | — | — | — | Chill. | 8·15 | 217 | 2·8 | 1,476 | 1,292 | 3,286 | 328 | 78 | — | 2,511 | 98 | ·401 | | | | | |
| | — | 30·9 | — | — | — | — | Com. | „ | 174 | 10·4 | 1,394 | 1,188 | — | — | — | — | — | — | — | | | | | |
| 21 c.m. of 9½ tons | — | 35·3 | — | — | — | — | Chill. | „ | 217 | 2·8 | 1,312 | 1,159 | 2,590 | 307 | 73 | — | 2,021 | 79 | ·401 | | | | | |
| | — | 26·5 | — | — | — | — | Com. | „ | 174 | 10·4 | 1,277 | 1,101 | — | — | — | — | — | — | — | | | | | |
| 17 c.m. of 5¾ tons | — | 26·5 | — | — | — | — | Chill. | 6·71 | 123 | 1·2 | 1,509 | 1,286 | 1,942 | 338 | 73 | — | 1,411 | 67 | ·407 | | | | | |
| | — | 22·0 | — | — | — | — | Com. | „ | 112 | 9·2 | 1,525 | 1,280 | — | — | — | — | — | — | — | | | | | |
| 17 c.m. of 5 tons | — | 17·6 | — | — | — | — | Chill. | „ | 123 | 1·2 | 1,279 | 1,109 | 1,395 | 279 | 79 | — | 1,040 | 50 | ·407 | | | | | |
| | — | 14·3 | — | — | — | — | Com. | „ | 103 | 6·6 | 1,279 | 1,082 | — | — | — | — | — | — | — | | | | | |
| 17 c.m. of 72 cwt. | — | 16·5 | — | — | — | — | Chill. | „ | 118 | 1·3 | 1,325 | 1,137 | 1,436 | 399 | 87 | — | 1,058 | 50 | ·390 | | | | | |
| | — | „ | — | — | — | — | Com. | „ | 113 | 5·9 | 1,342 | 1,142 | — | — | — | — | — | — | — | | | | | |
| 15 c.m. of 81 cwt. | — | 18·7 | — | — | — | — | Chill. | 5·85 | 78 | ·7 | 1,624 | 1,340 | 1,426 | 352 | 76 | — | 972 | 53 | ·390 | | | | | |
| | — | 15·4 | — | — | — | — | Com. | „ | 78 | 6·0 | 1,515 | 1,238 | — | — | — | — | — | — | — | | | | | |
| 15 c.m. of 72 cwt. | — | 13·2 | — | — | — | — | Chill. | „ | 78 | ·7 | 1,378 | 1,151 | 1,027 | 285 | 78 | — | 716 | 39 | ·390 | | | | | |
| | — | 12·1 | — | — | — | — | Com. | „ | 60 | 4·4 | 1,591 | 1,243 | — | — | — | — | — | — | — | | | | | |
| 15 c.m. of 66 cwt. | — | 13·2 | — | — | — | — | Chill. | „ | 78 | ·7 | 1,358 | 1,136 | 997 | 302 | 75 | — | 698 | 38 | ·390 | | | | | |
| | — | 12·1 | — | — | — | — | Com. | „ | 60 | 4·4 | 1,446 | 1,141 | — | — | — | — | — | — | — | | | | | |
| 12·5 c.m. of 29 cwt. | — | 8·8 | — | — | — | — | „ | 4·90 | 40 | 2·4 | 1,545 | — | — | — | — | — | — | — | — | | | | | |
| 12 c.m. of 29 cwt. | — | 4·6 | — | — | — | — | „ | 4·71 | 33 | 2·4 | 1,230 | — | — | — | — | — | — | — | — | | | | | |
| 8 c.m. of 7 cwt. | — | 1·1 | — | — | — | — | „ | 3·07 | 9·5 | ·6 | 1,115 | — | — | — | — | — | — | — | — | | | | | |
| 8 c.m. of 6¾ cwt. | — | „ | — | — | — | — | „ | „ | 9·5 | ·6 | 1,115 | — | — | — | — | — | — | — | — | | | | | |
| 8 c.m. of 4½ cwt. | — | ·9 | — | — | — | — | „ | 3·17 | 7·5 | ·6 | 1,132 | — | — | — | — | — | — | — | — | | | | | |
| 4 c.m. of 160 lbs. | — | ·4 | — | — | — | — | „ | 1·52 | 1·24 | ·02 | 1,837 | — | — | — | — | — | — | — | — | | | | | |

TABLE showing the Particulars of the latest Types of German Guns.

| Nature and Nominal Weight. | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | | Bore. | | | | Chamber. | | | Rifling. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Length in Inches. | Length in Calibres. | Diameter. | Capacity, including Powder Chamber. | Diameter. | Length. | Capacity. | Length. | Grooves. System. | Grooves. Number. | Grooves. Width. | Grooves. Depth. | Lands Width. | Twist. Nature. | Twist. No. of Calibre in which 1 turn is taken. | Twist. Angle. | |
| | | lbs. | ft. | in. | | | | c. in. | in. | in. | c. in. | | | | in. | in. | in. | | | ° | ′ |
| 40 c.m. of 71 tons | — | Nil | 32 | 10 | 343·0 | 21·8 | 15·75 | — | 17·32 | 61·37 | 14,456 | — | — | 90 | ·372 | ·079 | ·176 | Uniform. | 45 | 4 | 0 |
| 35·5 c.m. of 51 tons | — | „ | 29 | 2 | 304·7 | 21·8 | 13·98 | 47,810 | 14·37 | 42·67 | 6,920 | — | — | 80 | ·372 | ·079 | ·176 | | 45 | 4 | 0 |
| 30·5 c.m. of 38 tons | — | „ | 25 | 1 | 264·6 | 22·0 | 12·01 | 29,975 | 12·24 | 37·12 | 4,368 | — | — | 68 | ·374 | ·069 | ·176 | | 45 | 4 | 0 |
| 28 c.m. o 10 tons | — | „ | 10 | 6 | 99·4 | 9·0 | 11·02 | — | 11·26 | — | — | — | — | 64 | ·364 | ·069 | ·176 | | 35 | 5 | 8 |
| 24 c.m. of 17¾ tons | — | „ | 20 | 1 | 213·0 | 22·5 | 9·45 | 16,600 | 11·26 | 49·92 | 4,971 | — | — | 54 | — | ·059 | ·157 | | 45 | 4 | 0 |
| 15 c.m. of 78 cwt. | — | „ | 13 | 9 | 148·7 | 25·3 | 5·87 | — | 6·85 | — | 1,067 | — | — | 36 | ·374 | ·059 | ·137 | | 25 | 7 | 10 |
| 8·7 c.m. of 25 cwt. | — | 155· | 14 | 3 | 160·8 | 47·0 | 3·42 | — | 5·90 | — | — | — | — | 24 | ·331 | ·049 | ·118 | | 30 | 5 | 59 |

**TABLE showing the Ballistic Power of the latest Types of German Guns.**

| Nature and Nominal Weight. | Charges. | | | | | | Projectiles. | | | | Velocity. | | Energy in Foot Tons. | | | | | | | Trajectory for Range. | | | Accuracy. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | At Muzzle. | | | | At 1,000 Yards. | | | 600 Yards | 1,000 Yards. | | Mean error. | |
| | Powder. | Weight. | Cubic inch per lb. | Number of Expansions. | Maximum Pressure. | Mean Pressure in Powder Chamber. | Description. | Diameter. | Weight filled. | Burster. | Muzzle. | At 1,000 Yards. | Total. | Per ton of Gun. | Per lb. of Powder. | Per ton of mean Pressure. | Total. | Per Inch of Circumference. | Value of $\frac{w}{d^3}$. | Maximum Height above Gun and point aimed at. | Angle of Descent. | Dangerous Space. | Vertical. | Lateral. |
| | | lbs. | | | | | | in. | lbs. | lbs. | f. s. | f. s. | | | | | | | | | | | yds. | yds. |
| 40 c.m. of 71 tons | Prismatic, with one perforation; density, 1·75. | 452 | 31·98 | — | — | 19·8 | Chill. | 15·68 | 1,712 | 22·0 | 1,648 | 1,549 | 32,270 | 456 | 71 | 1,629 | 28,475 | 578 | ·444 | — | — | — | at 2,814 | |
| | | 441 | 32·80 | — | — | 19·8 | Com. | 15·74 | 1,417 | 73·3 | 1,761 | 1,635 | — | — | — | — | — | — | — | | | | ·15 | ·76 |
| 35·5 c.m. of 51 tons | | 253 | 27·30 | 6·82 | — | 21·0 | Chill. | 13·90 | 1,157 | 15·4 | 1,650 | 1,535 | 21,835 | 428 | 86 | 1,040 | 18,898 | 433 | ·431 | — | — | — | at 2,788 | |
| | | „ | „ | „ | — | „ | Com. | „ | 977 | 51·6 | — | — | — | — | — | — | — | — | — | | | | ·30 | 1·00 |
| 30·5 c.m. of 38 tons | | 159 | 27·52 | 6·80 | — | — | Chill. | 11·93 | 725 | 9·9 | 1,645 | 1,519 | 13,604 | 358 | 86 | — | 11,596 | 308 | ·427 | — | — | — | at 2,246 | |
| | | „ | „ | „ | — | — | Com. | „ | 622 | 32·6 | — | — | — | — | — | — | — | — | — | | | | ·45 | ·20 |
| 28 c.m. of 10 tons | Prismatic, 7 perforations. | 39·7 | — | — | — | — | Com. | 11·01 | 476 | 34·2 | 976 | 924 | 3,958 | 440 | 100 | — | 2,818 | 81 | ·357 | — | — | — | at 2,272 | |
| 24 c.m. of 17¾ tons | | 165 | 30·2 | 3·63 | — | 17·5 | Steel | 9·44 | 352 | 7·2 | 1,891 | 1,701 | 8,746 | 494 | 258 | 526 | 7,062 | 238 | ·418 | | | | ·83 | ·40 |
| | | „ | — | — | — | „ | Com. | 9·37 | 299 | 15·8 | 1,990 | 1,763 | — | — | — | — | — | — | — | — | — | — | at 2,228 | |
| 15 c.m. of 78 cwt. | | 33 | 32·3 | — | — | 16·8 | Steel | 5·86 | 112 | 3·3 | 1,668 | 1,461 | 2,161 | 558 | 66 | 129 | 1,657 | 90 | ·557 | | | | 1·00 | ·82 |
| | | „ | „ | — | — | 16·3 | Com. | „ | 88 | 11 | 1,834 | 1,555 | — | — | — | — | — | — | — | | | | | |
| 8·7 c.m. of 25 cwt. | Coarse grain. | 7·7 | — | — | — | 11·6 | Com. | 3·41 | 22 | ·66 | 1,829 | 1,459 | 511 | 413 | 72 | 44 | — | — | — | | | | | |
| | | „ | — | — | — | 10·1 | „ | „ | 15 | ? | 2,088 | 1,506 | 476 | 368 | 59 | 47 | — | — | — | | | | | |

TABLE showing the Particulars of Austrian Naval Guns.

| Nature and Nominal Weight. | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | Bore. Length in Inches. | Bore. Length in Calibre. | Bore. Diameter. | Bore. Capacity, including Powder Chamber. | Chamber. Diameter. | Chamber. Length. | Chamber. Capacity. | Rifling. Length. | Rifling. Grooves. System. | Rifling. Grooves. Number. | Rifling. Grooves. Width. | Rifling. Grooves. Depth. | Rifling. Lands. Width. | Rifling. Twist. Nature. | Rifling. Twist. No. of Calibre in which 1 turn is taken. | Rifling. Twist. Angle. | — |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cwt. | lbs. | ft. in. | in. | | in. | c. in. | | in. | | in. | | | in. | in. | in. | | | | |
| 28 c.m. of 27 tons | 20·1 | Nil | 20 0 | 207·2 | 18·8 | 11·02 | 19,798 | — | 36·5 | — | 170·7 | Parallel | 64 | 3·64 | ·069 | ·177 | Uniform. | 45 | 4° 0 | Krupp. |
| 26 c.m. of 22½ tons | 18·0 | „ | 18 9 | 194·6 | 19·0 | 10·24 | — | — | 46·1 | — | 148·5 | Wedge | 32 | — | — | — | | 70 | 2° 34′ | |
| 24 c.m. of 15¾ tons | 12·5 | „ | 17 2 | 177·7 | 19·1 | 9·27 | — | — | 41·7 | — | 136·0 | „ | 32 | — | — | — | | 70 | 2° 34′ | |
| 24 c.m. of 15 tons | 12·5 | „ | 15 5 | 156·7 | 16·9 | 9·27 | — | — | 41·7 | — | 115·0 | „ | 32 | — | — | — | | 64·7 | 2° 47 | |
| 21 c.m. of 9 tons | 9·6 | „ | 13 9 | 142·0 | 17·3 | 8·23 | — | — | 37·0 | — | 105·0 | „ | 30 | — | — | — | | 59 | 3° 3′ | |
| 15 c.m. of 31 cwt. | 3 | 157 | 12 8 | 135·0 | 23·0 | 5·87 | — | — | 29·3 | — | 105·7 | „ | 24 | — | — | — | | 68·4 | 2° 38′ | |
| 9-in. of 12 tons | — | 264 | 13 0 | 124·8 | 13·9 | 9·0 | 8,146 | — | — | — | 104·0 | Wool | 6 | 1·5 | ·18 | — | In. | 0 to 45 | 0 to 4° | Armstrong. |
| 7-in. of 6½ tons | — | 407 | 10 10 | 111·0 | 15·9 | 7·0 | 4,314 | — | — | — | 95·0 | „ | 3 | 1·5 | ·18 | — | Uniform. | 35 | 5° 8′ | |
| 15 c.m. of 58 cwt. | 1·6 | 310 | 10 2 | 107·8 | 18·3 | 5·87 | — | — | 17·9 | — | 89·8 | Parallel | 30 | — | — | — | | 68·2 | 2° 51′ | Wahrendorf. |
| 12 c.m. of 30 cwt. | 1·7 | 282 | 9 3 | 96·6 | 20·4 | 4·74 | — | — | 12·6 | — | 84·0 | „ | 24 | — | — | — | | 52·3 | 3° 26′ | |
| 15 c.m. of 69 cwt. | 1·8 | — | 12 2 | 135·0 | 23·0 | 5·87 | — | — | 31·5 | — | 103·5 | „ | 36 | — | — | — | | 45 | 4° 0′ | Uchatius. |
| 9 c.m. of 12 cwt. | ·5 | 107 | 6 9 | 73·5 | 21·4 | 3·43 | — | — | 16·5 | — | 57·0 | „ | 24 | — | — | — | | 45 | 4° 0′ | |
| 7 c.m. of 2 cwt. | ·2 | 51 | 3 3 | 34·8 | 13·4 | 2·60 | — | — | 11·0 | — | 23·8 | „ | 18 | — | — | — | | 30 | 5° 59′ | |

TABLE showing the Ballistic Power of Austrian Naval Guns.

| Nature and Nominal Weight. | Charges. Powder. | Charges. Weight. | Charges. Cubic inch per lb. | Charges. Number of Expansions. | Charges. Maximum Pressure. | Charges. Mean Pressure in Powder Chamber. | Projectiles. Description. | Projectiles. Diameter. | Projectiles. Weight filled. | Projectiles. Burster. | Velocity. Muzzle. | Velocity. At 1,000 Yards. | Energy in Foot Tons. At Muzzle. Total. | Energy in Foot Tons. At Muzzle. Per ton of Gun. | Energy in Foot Tons. At Muzzle. Per lb. of Powder. | Energy in Foot Tons. At Muzzle. Per ton of Pressure. | Energy in Foot Tons. At 1,000 Yards. Total. | Energy in Foot Tons. At 1,000 Yards. Per inch of Circumference. | Value of $\frac{w}{d^3}$. | Trajectory for Range. 600 Yards. Maximum Height above Gun and point aimed at. | Trajectory for Range. 1,000 Yards. Angle of Descent. | Trajectory for Range. 1,000 Yards. Dangerous Space. | Accuracy at 1,000 Yards. Size of Vertical Target to contain 25 per cent. of hits. Height. | Accuracy at 1,000 Yards. Size of Vertical Target to contain 25 per cent. of hits. Breadth. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | lbs. | | | | | | in. | | lbs. | f. s. | f. s. | | | | | | | | | | | | |
| *Krupp.* | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 c.m. of 27 tons | Prismatic. | 121·2 | — | 5·9 | — | — | Steel | 10·94 | 560 | 14·3 | — | — | — | — | — | — | — | — | ·427 | | | | | |
| | | " | — | — | — | — | Chilled | " | 575 | 7·7 | 1,542 | 1,405 | 9,480 | 351 | 80 | — | 7,871 | 228 | ·439 | | | | | |
| | | " | — | — | — | — | Common | " | 487 | 25·3 | 1,673 | 1,504 | — | — | — | — | — | — | — | | | | | |
| 28 c.m. of 22½ tons | | 70·5 | — | — | — | — | Steel | 10·22 | 396 | 8·8 | 1,404 | 1,254 | 5,415 | 243 | 77 | — | 4,318 | 134 | ·371 | | | | | |
| | | 59·5 | — | — | — | — | Common | " | 354 | 20·3 | 1,378 | 1,217 | — | — | — | — | — | — | — | | | | | |
| 24 c.m. of 15½ tons | | 52·9 | — | — | — | — | Steel | 9·25 | 292 | 6·6 | 1,421 | 1,253 | 4,082 | 259 | 77 | — | 3,179 | 109 | ·369 | | | | | |
| | | 44·1 | — | — | — | — | Common | " | 263 | 15 | 1,378 | 1,203 | — | — | — | — | — | — | — | | | | | |
| 24 c.m. of 15 tons | | 52·9 | — | — | — | — | Steel | " | 292 | 6·6 | 1,378 | 1,218 | 3,845 | 256 | 73 | — | 3,004 | 103 | ·369 | | | | | |
| | | 52·9 | — | — | — | — | Chilled | " | 309 | 3·7 | 1,345 | 1,199 | 3,876 | 258 | 73 | — | 3,080 | 106 | ·390 | | | | | |
| | | 44·1 | — | — | — | — | Common | " | 263 | 15 | 1,329 | 1,164 | — | — | — | — | — | — | — | | | | | |
| 21 c.m. of 9 tons | | 37·5 | — | — | — | — | Steel | 8·21 | 207 | 4·4 | 1,394 | 1,215 | 2,789 | 310 | 74 | — | 2,119 | 82 | ·374 | | | | | |
| | | 30·9 | — | — | — | — | Chilled | " | 196 | 3·1 | 1,253 | 1,098 | 2,134 | 237 | 69 | — | 1,638 | 63 | ·354 | | | | | |
| | | 30·9 | — | — | — | — | Common | " | 172 | 15 | 1,345 | 1,147 | — | — | — | — | — | — | — | | | | | |
| 15 c.m. of 81 cwt. | | 17·6 | — | — | — | — | Steel | 5·85 | 74 | 1·6 | 1,608 | 1,314 | 1,330 | 332 | 75 | — | 886 | 48 | ·370 | | | | | |
| | | 14·3 | — | — | — | — | Common | " | 67 | 3·8 | 1,509 | 1,213 | — | — | — | — | — | — | — | | | | | |
| *Armstrong M.L.* | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 in. of 12 tons | P. | 50 | — | 5·7 | — | — | Chilled | 8·92 | 249 | 5·9 | 1,486 | 1,293 | 3,813 | 318 | 76 | — | 2,887 | 103 | ·352 | | | | | |
| | ? | 30 | — | 9·6 | — | — | Common | " | 258 | 18·5 | 1,082 | 996 | — | — | — | — | — | — | — | | | | | |
| 7 in. of 6½ tons | P. | 28·7 | — | — | — | — | Chilled | 6·92 | 115 | 1·1 | 1,512 | 1,262 | 1,823 | 280 | 63 | — | 1,270 | 58 | ·347 | | | | | |
| | ? | 13·2 | — | — | — | — | Common | " | 121 | 7·9 | 1,108 | 990 | — | — | — | — | — | — | — | | | | | |
| *Wahrendorf B.L.* | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 c.m. of 58 cwt. | ? | 4·7 | — | — | — | — | " | 5·83 | 61 | 1·9 | 1,017 | 902 | 439 | 146 | 90 | — | — | — | — | | | | | |
| 12 c.m. of 30 cwt. | ? | 2·4 | — | — | — | — | " | 4·70 | 32 | 1·1 | 1,001 | 866 | 223 | 150 | 93 | — | — | — | — | | | | | |
| *Uchatius B.L.* | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 c.m. of 69 cwt. | ? | 21·0 | — | — | — | — | " | 5·85 | 70 | 5·0 | 1,692 | 1,368 | 1,390 | 400 | 66 | — | — | — | ·350 | | | | | |
| 9 c.m. of 10 cwt. | ? | 3·3 | — | — | — | — | " | ? | 14 | ·44 | 1,470 | ? | 210 | — | — | — | — | — | — | | | | | |
| 7 c.m. of 200 lbs. | ? | ·77 | — | — | — | — | " | ? | 6·4 | ·17 | 978 | ? | 42 | — | — | — | — | — | — | | | | | |

## TABLE showing the Particulars of Italian Naval Guns.

| Nature and Nominal Weight. | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | Bore. | | | | Chamber. | | | Rifling. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Grooves. | | | | Lands | Twist. | | |
| | | | | Length in Inches. | Length in Calibres. | Diameter. | Capacity, including Powder Chamber. | Diameter. | Length. | Capacity. | Length. | System. | Number. | Width. | Depth. | Width. | Nature. | No. of Calibre in which 1 turn is taken at | Angle. |
| | cwt. | cwt. | ft. in. | | | in. | c. in. | | in. | c. in. | in. | | | in. | in. | | | B. M. | B. M. |
| 45 c.m. of 100 tons - | M.L. | 89½ | 32 10 | 363 | 20 | 17·72 | 92,700 | 19·7 | 59·72 | 16,957 | 302·9 | Poly. | 28 | 1·1 | ·125 | — | In. | 150 50 | 1° 12 3 36′ |
| 28 c.m. of 25 tons - | „ | Nil. | 14 5 | 144·9 | 13·1 | 11 | — | — | — | — | 120·4 | Wool | 9 | — | — | — | In. | 0 35 | 0° 5° 59′ |
| 28 c.m. of 25 tons - | „ | „ | „ | „ | „ | „ | — | — | — | — | 118·9 | „ | 8 | — | — | — | „ | 100 45 | 1° 48′ 4° 0 |
| 25 c.m. of 17¾ tons - | „ | „ | 14 5 | 145·4 | 14·5 | 10 | — | — | — | — | 119·4 | „ | 7 | — | — | — | „ | 100 40 | 1° 48′ 4° 29′ |
| 25 c.m. of 18 tons - | „ | „ | 14 0 | 140·0 | 14·0 | „ | — | — | — | — | 114·0 | „ | 7 | — | — | — | „ | 100 40 | 1° 48′ 4° 29′ |
| „ of 12 tons - | „ | 5¼ | 13 0 | 127·2 | 12·7 | — | — | — | — | — | 113·2 | „ | 8 | — | — | — | U. | 55 | 3° 16′ |
| 22 c.m. of 12¾ tons - | „ | Nil. | 13 0 | 125·2 | 13·9 | 9 | — | — | — | — | 105·7 | „ | 6 | — | — | — | In. | 0 45 | 0° 4° 0′ |
| 20 c.m. of 7 tons - | „ | 7¼ | 10 10 | 104·3 | 13·0 | 8 | — | — | — | — | 88·6 | „ | 6 | — | — | — | U. | 45 | 4° 0′ |
| 16 c.m. of 5 tons - | „ | 9½ | 11 10 | 105·4 | 16·2 | 6·5 | — | — | — | — | 91·6 | „ | 6 | — | — | — | „ | 42 5 | 4° 14′ |
| 16 c.m. of 71 cwt. - | „ | 8¼ | 10 6 | 108·3 | 16·6 | 6·5 | — | — | — | — | 94·3 | „ | 6 | — | — | — | „ | 42·5 | 4° 14′ |
| 12 c.m. of 23¾ cwt. - | 1 | 2 | — | 96·1 | 20·4 | 4·7 | — | — | — | — | 76·6 | Poly. | 27 | — | — | — | — | — | — |

**TABLE showing the Ballistic Power of Italian Naval Guns.**

| Nature and Nominal Weight. | Charge. | | | | | | Projectiles. | | | | Velocity. | | Energy in Foot Tons. | | | | | | | Trajectory for Range. | | | Accuracy at 1,000 Yards. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | At Muzzle. | | | | At 1,000 Yards. | | | 600 Yards. | 1,000 Yards. | | Size of Target to contain 25 percent. Hits. | |
| | Powder. | Weight. | Cubic in. per lb. | Number of Expansions. | Maximum Pressure. | Mean Pressure in Powder Chamber. | Description. | Diameter. | Total Weight filled. | Burster. | Muzzle. | At 1,000 Yards. | Total. | Per ton of Gun. | Per lb. of Powder. | Per ton of Maximum Pressure. | Total. | Per In. of Circumference. | Value of $\frac{w}{d^3}$ | Maximum Height above Gun and point aimed at. | Angle of Descent. | Dangerous Space. | Height. | Breadth. |
| | | lbs. | | | tons | tons | | in. | lbs. | lbs. | f.s. | f.s. | | | | | | | | feet. | ° ′ | yds. | yds. | yds. |
| 45 c.m. of 100 tons | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 c.m. of 25 tons - | | 95 | — | — | — | — | Chill. | 10·92 | 535 | 5·5 | 1,312 | 1,197 | 6,386 | 255 | 67 | — | 5,315 | 155 | ·412 | | | | | |
| | | ,, | — | — | — | — | Com. | ,, | ,, | 26·0 | ,, | ,, | — | — | — | — | — | — | — | | | | | |
| 25 c.m. of 17¾ and 18 tons - | | 77 | — | — | — | — | Chill. | 9·92 | 392 | 5·1 | 1,409 | 1,265 | 5,396 | 300 | 70 | — | 4,350 | 139 | ·392 | | | | | |
| | | ,, | — | — | — | — | Com. | ,, | 399 | 23·8 | 1,398 | 1,258 | — | — | — | — | — | — | — | | | | | |
| 25 c.m. of 12 tons - | | 64 | — | — | — | — | Chill. | ,, | 289 | 3·3 | 1,409 | 1,220 | 3,978 | 331 | 62 | — | 2,983 | 96 | ·289 | | | | | |
| | | ,, | — | — | — | — | Com. | ,, | 285 | 18·2 | 1,419 | 1,225 | — | — | — | — | — | — | — | | | | | |
| 22 c.m. of 12¾ tons | | 59 | — | — | — | — | Chill. | 8·92 | 240 | 2·5 | 1,476 | 1,285 | 3,672 | 288 | 62 | — | 2,851 | 101 | ·352 | | | | | |
| | | ,, | — | — | — | — | Com. | ,, | 251 | 18·7 | ,, | 1,286 | — | — | — | — | — | — | — | | | | | |
| 20 c.m. of 7 tons - | | 44 | — | — | — | — | Chill. | 7·92 | 157 | 1·3 | ,, | 1,213 | 2,372 | 339 | 54 | — | 1,684 | 68 | ·316 | | | | | |
| | | ,, | — | — | — | — | Com. | ,, | 149 | 9·6 | 1,509 | 1,257 | — | — | — | — | — | — | — | | | | | |
| 16 c.m. of 5 tons - | | 20 | — | — | — | — | Steel | 6·42 | 123 | — | 1,296 | 1,135 | 1,432 | 286 | 72 | — | 1,090 | 54 | ·465 | | | | | |
| | | ,, | — | — | — | — | Com. | ,, | 66 | 3·3 | 1,425 | 1,106 | — | — | — | — | — | — | — | | | | | |
| 16 c.m. of 71 cwt. | | 7·7 | — | — | — | — | Com. | ,, | 66 | 3·3 | 1,030 | 900 | — | — | — | — | — | — | — | | | | | |
| 12 c.m. of 23¾ cwt. | | 5·5 | — | — | — | — | Com. | 4·68 | 35 | 2·6 | 1,367 | 1,070 | 453 | 377 | 82 | — | 278 | 19 | — | | | | | |

## TABLE showing the Particulars of Armstrong Guns.

| Nature and Nominal Weight. | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | | Bore. | | | | Chamber. | | | Rifling. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Length in Inches. | Length in Calibres. | Diameter. | Capacity including Powder Chamber. | Diameter. | Length. | Capacity. | Length. | Grooves. | | | | Lands | Twist. | | | | | |
| | | | | | | | | | | | | | System. | Number. | Width. | Depth. | Width. | Nature. | No. of Calibre in which 1 turn is taken. | | Angle. | | |
| | | cwt. | ft. | in. | | | in. | c. in. | in. | in. | c. in. | in. | | | in. | in. | in. | | B. | M. | B. | M. | |
| 11″ of 35 tons . | — | 19 | 22 | 10 | 255 | 23·2 | 11 | 27,437 | 14·0 | 58·6 | 8,460 | 198 | | 21 | ·818 | ·1 | ·818 | | 80 | 45 | 2° 15′ | 4° | |
| 10″ of 25 tons . . | — | 0 | 22 | 11 | 259 | 26·0 | 10 | 23,400 | 13·3 | 52·7 | 6,650 | 202 | | 42 | ·448 | ·025 | ·3 | | 150 | 45 | 1° 12′ | 4° | |
| 9″ of 18 tons* . . | — | 1 | 20 | 8 | 234 | 26·0 | 9 | 16,888 | 11·5 | 54·5 | 5,400 | — | | — | — | — | — | | — | | — | | |
| 8″ of 11½ tons . . | — | 0 | 18 | 5 | 208 | 26·0 | 8 | 11,589 | 10·0 | 43·5 | 3,240 | 162 | Polygroove. | 33 | ·462 | ·025 | ·3 | Increasing. | 150 | 45 | 1° 12′ | 4° | |
| 7″ of 7 tons . . | — | 0 | 15 | 0 | 168 | 24·0 | 7 | 7,051 | 8·5 | 34·5 | 1,750 | 135 | | 20 | ·75 | ·1 | ·35 | | 0 | 45 | 0° | 4° | |
| 6″ of 4 tons . . | — | 0 | 13 | 10 | 156 | 26·0 | 6 | 4,827 | 7·5 | 27·4 | 1,155 | 126 | | 23 | ·423 | ·025 | ·25 | | 0 | 40 | 0° | 4°30′ | |
| 40 pr. of 26½ cwt. . | — | ½ | 9 | 4 | 104 | 22·0 | 4·72 | 1,875 | 4·92 | 13·9 | 275 | 89 | | 22 | ·4 | ·025 | ·274 | | 100 | 40 | 1°48 | 4°30′ | |

* Not yet completed.

**TABLE showing the Ballistic Power of Armstrong Guns.**

| Nature and Nominal Weight. | Charge. | | | | | | Projectiles. | | | | Velocity. | | Energy in Foot Tons. | | | | | | Value of $\frac{w}{d^3}$. | Trajectory for Range. | | | Accuracy at 1,000 Yards. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | At Muzzle. | | | | At 1,000 Yards. | | | 600 Yards. | 1,000 Yards. | | Size of Target to contain 25 per cent. Hits. | |
| | Powder. | Weight. | Cubic in. per lb. | Number of Expansions. | Maximum Pressure. | Mean Pressure in Powder Chamber. | Description. | Diameter. | Total Weight filled. | Burster. | Muzzle. | At 1,000 Yards. | Total.* | Per ton of Gun. | Per lb. of Powder. | Per ton of Maximum Pressure. | Total. | Per In. of Circumference. | | Maximum Height above Gun and Point aimed at. | Angle of Descent. | Dangerous Space. | Height. | Breadth. |
| | | lbs. | | | | | | in. | lbs. | lbs. | f.s. | f.s. | | | | | | | | † ft. | † ° ′ | † yds. | yds. | yds. |
| 11″ of 35 tons | Peb | 235 | 36 | 4·22 | 20 to 23 tons. | 15 to 18 tons. | Chill. | 10·94 | 535 | 6·5 | 1,875 | 1,708 | 13,050 | 373 | 55 | — | 10822 | 315 | ·408 | 3·9 | 0 54 | 423 | | |
| 10″ of 25 tons | | 190 | 35 | 4·35 | | | „ | 9·94 | 400 | 6·9 | 2,000 | 1,807 | 11,094 | 433 | 58 | — | 9,047 | 290 | ·407 | 3·5 | 0 48 | Whole range. | | |
| 9″ of 18 tons | „ | 150 | 36 | 4·06 | | | „ | 8·94 | 250 | 5 | 2,250 | 1,963 | 8,700 | 483 | 58 | — | 6,680 | 238 | ·350 | 2·8 | 0 40 | | | |
| 8″ of 11¼ ton | „ | 90 | 35·6 | 4·76 | | | | 7·94 | 180 | 3 | 2,027 | 1,754 | 5,133 | 446 | 57 | — | 3,843 | 154 | ·360 | 3·5 | 0 50 | | | |
| | | | | | | | Com. | „ | 182 | — | 1,984 | — | — | — | — | — | — | — | — | — | — | — | at 4,530 yds. 3·4 | |
| 7″ of 7 tons | „ | 50 | 35 | 5·08 | | | Chill. | 6·94 | 115 | 1·6 | 1,850 | 1,549 | 2,729 | 390 | 55 | — | 1,913 | 88 | ·344 | 4·2 | 1 3 | 362 | | |
| 6″ of 4 ton | „ | 35 | 33 | 4·97 | | | „ | 5·97 | 80 | 1·5 | 1,930 | 1,601 | 2,069 | 517 | 59 | — | 1,424 | 76 | ·376 | 3·9 | 0 59 | 388 | | |
| 40-pr. of 26¼ cwt. | „ | 8 | 64·4 | 8·45 | | | Com. | 4·69 | 40 | 2·4 | — | — | — | — | — | — | — | — | ·388 | — | — | — | | |

† Approximate only.

**TABLE showing the Particulars of Russian Naval Rifled Guns.**

N.B.—Some smooth-bore guns are mounted in Russian ships.

| Nature and Nominal Weight. | Weight of Breech Arrangement. | Preponderance. | Extreme Length. | Bore. | | | | Chamber. | | | Rifling. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length in Inches. | Length in Calibres. | Diameter. | Capacity, including Powder Chamber. | Diameter. | Length. | Capacity. | Length. | Grooves. System. | Grooves. Number. | Grooves. Width. | Grooves. Depth. | Lands. Width. | Twist. Nature. | Twist. No. of Calibre in which 1 turn is taken. | Twist. Angle. |
| | cwt. | cwt. | ft. in. | | | in. | cub. n. | in. | in. | cub. in. | in. | | | in. | in. | in. | | | ° ′ |
| 12″ of 40 tons | — | 17½ | 21 0 | — | — | 12·01 | — | — | — | — | — | | 36 | — | — | — | — | — | — |
| 11″ of 28 tons | — | 0 | 18 5 | — | — | 11·00 | — | — | — | — | — | | 36 | — | — | — | | 70 | 2 34 |
| 9″ of 15 tons | — | 4 | 15 0 | — | — | 9·03 | — | — | — | — | — | | 32 | — | — | — | | 60 | 3 0 |
| 9″ of 12 tons | — | 6¾ | 13 0 | — | — | 9·03 | — | — | — | — | — | | 32 | — | — | — | Uniform | 60 | 3 0 |
| 8″ of 9 tons | — | 4 | 14 7 | — | — | 7·98 | — | — | — | — | — | | 30 | — | — | — | | 60 | 3 0 |
| 6″ of 4½ tons | — | 3 | 11 10 | — | — | 5·99 | — | — | — | — | — | | 24 | — | — | — | | 45 | 4 0 |
| AMERICAN RIFLED GUNS. | | | | | | | | | | | | | | | | | | | |
| 12¼″ of 40 tons L.S. | M.L. | ½ | — | 227 | 18·5 | 12·25 | — | — | — | — | 207 | — | 21 | ·916 | ·09 | ·917 | — | 57 | — |
| 10″ of 18 tons L.S. | ,, | — | 14 10 | 147 | 14·7 | 10·00 | — | — | — | — | 129 | — | 17 | ·924 | ·08 | ·924 | — | 60 | 3 0 |
| 8″ of 7¾ tons L.S. | ,, | 1½ | 11 5 | 117 | 14·6 | 8·00 | — | — | — | — | 107 | — | 15 | ·838 | ·075 | ·838 | — | 60 | 3 0 |
| 8″ of 8 tons S.S. | ,, | — | — | 129 | 16·1 | 8·00 | 6,393 | — | — | — | — | — | — | — | — | — | — | — | — |
| 80 pr. of 4½ tons S.S. | B.L. | — | — | 129 | 20·1 | 6·40 | 4,070 | — | — | — | — | — | 9 | 1·26 | ·10 | 1·26 | — | — | — |

TABLE showing the Ballistic Power of Russian Naval Guns.

| Nature and Nominal Weight | Charge. | | | | | | Projectiles. | | | | Velocity. | | Energy in Foot Tons. | | | | | | | Trajectory for Range. | | | Accuracy at 1,000 Yards. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | At Muzzle. | | | | At 1,000 Yards. | | | 600 Yards. | 1,000 Yards. | | Size of Target to contain 25 per cent. Hits. | |
| | Powder. | Weight. | Cubic in. per lb. | Number of Expansions. | Maximum Pressure. | Mean Pressure in Powder Chamber. | Description. | Diameter (?). | Total Weight filled. | Burster. | Muzzle. | At 1,000 Yards. | Total. | Per ton of Gun. | Per lb. of Powder. | Per ton of Maximum Pressure. | Total. | Per In. of circumference. | Value of $\frac{w}{d^2}$ | Maximum Height above Gun and point aimed at. | Angle of Descent. | Dangerous Space. | Height. | Breadth. |
| | | lbs. | | | tons. | tons. | | in. | lbs. | lbs. | f.s. | f.s. | | | | | | | | †feet. | †° ′ | †yds. | yds. | yds. |
| 12″ of 40 tons | — | 121 | — | — | — | — | Steel | 11·93 | 650 | — | 1,446 | 1,314 | 9,424 | — | 78 | — | 7,782 | 208 | ·383 | 6·6 | 1 32 | 249 | — | — |
| | — | — | — | — | — | — | Com. | „ | 644 | 15·8 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 11″ of 28 tons | — | 82 | — | — | — | — | Steel | 10·92 | 494 | 12·1 | 1,286 | 1,167 | 5,665 | — | 69 | — | 4,665 | 136 | ·379 | 8·4 | 1 56 | 197 | — | — |
| | — | — | — | — | — | — | Com. | „ | 426 | 14·0 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 9″ of 15 tons | — | 47 | — | — | — | — | Steel | 8·95 | 271 | 7·7 | 1,338 | 1,185 | 3,364 | — | 71 | — | 2,639 | 94 | ·378 | 7·8 | 1 51 | 206 | — | — |
| | — | — | — | — | — | — | Com. | „ | 258 | 9·4 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 9″ of 12 tons | — | 43 | — | — | — | — | Steel | „ | 271 | 7·7 | 1,260 | 1,123 | 2,983 | — | 69 | — | 2,370 | 84 | ·378 | 8·8 | 2 4 | 184 | — | — |
| | — | — | — | — | — | — | Com. | „ | 258 | 9·4 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 8″ of 9 tons | — | 28 | — | — | — | — | Steel | 7·90 | 176 | 4·8 | 1,383 | 11,93 | 2,334 | — | 83 | — | 1,737 | 70 | ·357 | 7·5 | 1 48 | 211 | — | — |
| | — | — | — | — | — | — | Com. | „ | 176 | 6·0 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 6″ of 4½ tons | — | 18 | — | — | — | — | Steel | 5·91 | 96 | — | 1,334 | 1,151 | 1,185 | — | 66 | — | 882 | 47 | ·465 | 8·0 | 1 57 | 196 | — | — |
| | — | „ | — | — | — | — | Com. | „ | 81 | 2·8 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| AMERICAN RIFLED GUNS. | | | | | | | | | | | | | | | | | | | | | | | | |
| 12¼″ of 40 tons L.S.* | — | 115 | — | — | — | 15 | Butler | 12·18 | 700 | — | 1,485 | 1,353 | 10,704 | 267 | 93 | — | 8,886 | 232 | ·387 | 6·3 | 1 26 | 265 | — | — |
| 10″ of 18 tons, L.S. | — | 70 | — | — | 10 | — | „ | 9·44 | 400 | — | 1,389 | 1,250 | 5,439 | 297 | 76 | 535 | 4,338 | 138 | ·407 | 7·3 | 1 41 | 227 | — | — |
| 8″ of 7½ tons, L.S. | — | 35 | — | — | 15 | — | „ | 7·95 | 186 | — | 1,374 | 1,192 | 244 1 | 340 | 69 | 162 | 1,837 | 73 | ·370 | 7·5 | 1 49 | 209 | — | — |
| 8″ of 8 tons, S.S. | — | 35 | 27·5 | 6·59 | — | 11·5 | „ | 7·95 | 180 | — | 1,475 | 1,267 | 2,718 | 354 | 78 | — | 2,004 | 80 | ·358 | 6·5 | 1 36 | 239 | — | — |
| 80-pr. of 4½ tons, S.S. | — | 10 | 27·3 | 14·8 | — | 7·0 | Parrott | 6·35 | 80 | — | 1,250 | — | 871 | — | 87 | — | — | — | — | — | — | — | — | — |

* Experimental.

† Approximate only.

# CHAPTER XIV.

## ARMAMENT.

A question, on which much difference of opinion exists, is the proper armament for ships, that is, the number and weight of the guns which they should carry.

Primary idea.

The primary idea, from the gunnery point of view, is to ascertain the weight and arrangement of armament, which under the normal conditions of a naval engagement shall give the greatest number of effective hits.

Now naval actions may be divided into two broad classes:—

1. Duels—
2. Fleet actions—

And the conditions of the two are somewhat different.

The unarmoured cruiser should be armed for the duel, since it will never take other than a secondary part in a fleet action; while in the case of the battle ship, fleet actions must also be considered.

### Guns.

Measure of power of guns.

Speaking generally, it may be considered that the effect of guns of equal weight is measured by—

1. Flatness of trajectory.
2. Penetration.
3. Shell power.
4. Rapidity of fire.
5. Accuracy.

These different qualities are naturally so intimately connected that they must be considered with reference to each other, the conditions required for the one being in some cases opposed to those necessary for the other.

Flatness of trajectory.

1. Flatness of trajectory.—This is the most essential quality in a naval gun, and requires, in the first place, a high muzzle velocity; and, in the second, the power of retaining this velocity. These conditions entail certain limits, between which the weight and dimensions of the projectile must be kept. Thus, for a given calibre, strength, and length of gun, there is some particular weight of projectile which will give the best results

up to a given range. A lighter projectile would be more effective at shorter distances, while a heavier one would have the advantage at longer ranges.

2. Penetration.—This requires a high remaining, or striking, velocity, and the conditions entailed are mentioned above. In order to withstand the shock of striking an iron plate, it also necessitates a projectile made with thick walls, and therefore of limited interior capacity. Penetration.

3. Shell power.—This requires a large projectile having great interior capacity, and therefore comparatively weak, and these conditions are opposed to penetration, and, beyond a certain point, to flatness of trajectory. Shell power.

4. Rapidity of fire requires simple and effective arrangements for working the gun. In the case of very heavy guns the use of hydraulic or other machinery adds greatly to the rapidity with which they can be worked. Rapidity.

5. Accuracy.—The difference in the accuracy of modern rifled guns is so small that, from a naval point of view, it is not of much importance. At the same time, there is no reason why this quality should not be combined with other more essential ones. Accuracy.

A table is annexed showing the weights, muzzle velocity, power of penetration, and shell power some service guns.

It is assumed by some that the effect of a shell bursting is proportional to the square of the bursting charge, and therefore this is also given for purposes of comparison.

| — | Total Weight with Stores.† | Average Weight of Projectile. | Muzzle Velocity. | Piercing power at 500 yards. Iron Plates, in inches. | Common. | | Palliser. | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Burster. | Square of Do. | Burster. | Square of Do. |
| | Tons. | | | | | | | |
| Turret, 12½in., 38 ton* | 145 | 818 | 1,415 | 18·2 | 27 | 729 | 11¾ | 138 |
| Side, 11 " 25 " | 64 | 535 | 1,315 | 13·8 | 30 | 900 | 6½ | 42 |
| " 10 " 18 " | 49 | 400 | 1,364 | 12·7 | 20 | 400 | 6⅞ | 47 |
| " 9 " 12½ " | 31 | 250 | 1,420 | 10·4 | 19 | 361 | 5½ | 30 |
| " 8 " 9 " | 24 | 180 | 1,413 | 9·0 | 14½ | 210 | 4½ | 20 |
| " 7 " 6½ " | 17 | 115 | 1,540 | 8·0 | 8¾ | 76 | 2½ | 6 |
| | | | | | | | Double | Shell. |
| " 7 " 4½ " | 14½ | 115 | 1,360 | — | 8¾ | 76 | 10¾ | 115 |
| " 64-pr., 64cwt. with slides. | 8¼ | 64 | 1,380 | — | 7 | 49 | — | — |

* 130 lbs. charge.

† These are the weights of stores, &c. for one gun, supposing that there are four guns of that size in the ship.

Heavy or light guns.

When it has been decided what weight can be allowed for the total armament of a ship, the next question to settle is, Shall this weight be distributed among a few heavy guns, or a larger number of less individual weight?

The arguments in favour of the few heavy guns are—increased penetration and more efficient control.

While those in favour of the many lighter guns are that the larger number renders it less likely that they will all be disabled, and that the chance of hitting is increased with the number of guns.

## Unarmoured Cruisers.

### *Light.*

Size of gun.

The size of the gun is ruled by ne fact that every hit must be effective. This depends upon the object to be fired at, which in the case of these cruisers is an unarmoured ship—a cruiser.

So that the question really becomes, what gun is effective against cruisers? This point has been partly decided by experiments (*vide* p. 255), which would seem to indicate that a 3-ton gun is the lightest and a 5-ton gun the heaviest which should be used for the purpose.

A lighter gun would not inflict fatal injuries, and a heavier one would not produce an effect commensurate to the increased weight.

The improvements which have been introduced into the structural arrangements of unarmoured ships, and the introduction of protected cruisers, such as the "Comus" class, may necessitate a further series of experiments, which may lead to a modification of the above. It must, however, be remembered that the power of artillery is also being rapidly developed, so that it is possible that the same limits of weight may still hold good.

Number of guns.

It has been shown that firing the guns singly is the system which would probably give the best results when it can be used, and that the most difficult conditions for hitting are rapid changes in the distance and bearing. The cruiser, whose armament is best suited to independent firing under these circumstances, will, therefore, have the advantage.

It has been seen under the head of systems of firing that a comparatively small number of guns meets these requirements.

The exact number always must be very much a matter of opinion, but experiment might enable a tolerable approximation to be made.

The most economically armed cruiser would, therefore, be one whose size is such that her battery is composed of this number of effective guns.

For a larger ship the battery must be composed either of a greater number of guns, which would not give a proportionately increased number of hits, or of heavier guns, which would be superfluous, since the smaller ones are sufficient for the work. **Best armament for Cruisers.**

For a smaller vessel with a battery of less total weight, the best result will be obtained by keeping the same number, but reducing the size of each gun until the smallest effective gun is reached, after which the number of guns must be reduced.

### *Heavy.*

In the larger type of cruiser we must consider in addition the possibility of these ships being called on to engage a belted cruiser or light ironclad. In this eventuality the increased penetration due to a larger gun becomes an important factor, and with the present ordnance qualifies the above statements, so far as relates to the size of the gun. As may be seen, however, by reference to the performance of the newer types of guns in the diagram, p. 272, great powers of penetration could be obtained without much exceeding the limits of five tons. **Heavy Cruisers.**

## BATTLE SHIPS.

### *Completely Armoured.*

The primary object aimed at in the construction and armament of an ironclad is that she may be capable of meeting certain other ironclads on equal or superior terms, and, therefore, her armament depends upon :— **Conditions on which armament depends.**

1. The armoured or other protection of her probable opponent.
2. The amount of protection required for her own guns.
3. Tactical considerations.

As in the case of unarmoured ships, every hit should be effective, and therefore the first affects the size of the gun, and hence the number.

Position depends on protection and tactics.

The second and third determine the positions where they shall be placed, and therefore also the number.

If the type of ship to which she is likely to be opposed is such that the vital parts are completely armoured, then every gun must be capable of perforating this armour. This will be found as a rule to necessitate guns of such size that their number will be limited by considerations of weight. The great reduction in numbers from this cause renders it of the first importance that the guns should be so placed that each can be effectively protected and be used with maximum effect. As stated above this question of *position* is partly tactical and partly structural, and as it has not yet been completely worked out, it is uncertain to what extent it influences the number of guns.

Existing ironclads.

As regards existing broadside ironclads, the number of guns has been limited by considerations of penetrating power and of position only so far as this last is governed by the necessity of giving adequate protection. In the case of turret ships the system has also limited the number of turrets and heavy guns.

Effect of tactics on position.

As to the effect of tactics on position it may be said that in a fleet action the risk of hitting friendly ships, added to the difficulty of allowing for rapid changes in the distance and bearing, renders it very important that the guns shall be so placed that they may be effectively controlled by a few officers, who should, if possible, have an unrestricted view. It was chiefly with this object that electric firing was introduced into broadside ships.

Barbette.

The introduction of the barbette system will probably meet the tactical requirements in this respect.

Single turret.

As an instance of the influence of tactics the single turret ship may be mentioned in which the position of the turret forward or aft depends on tactical considerations.

## *Partially Armoured.*

Partially armoured.

If, however, the enemies' ships are only partially armoured, and are so constructed that serious injuries can be inflicted on them by destroying the unarmoured parts, then a mixed armament seems to be desirable, part being effective against the armoured and the remainder against the unarmoured parts.

The relative proportion of the weight to be allotted to these two descriptions of guns is a difficult question.

The size of the armour-piercing guns of the primary armament is fixed by piercing power, and their number by weight and position as in the last case.

The secondary armament is dependent upon considerations similar to those which determine the armament of unarmoured ships, and in addition upon the necessity that the fire of the large guns must not be interfered with. Secondary armament.

This class of ship may be looked upon as composed of n armoured combined with an unarmoured ship.

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# CHAPTER XV.

## SHIPS.

### General Remarks.

Classes.

Men-of-war may be divided into two broad classes:—

Armoured ships.
Unarmoured ships.

These divisions may each be again sub-divided into smaller classes according to size, power, and the purpose for which they are designed.

Gradual development.

Ironclad navies (and especially the English) have grown up by progressive steps, so that it is rare to find many ships of the same design, and consequently the ships in each division are grouped merely according to general resemblance.

Distribution of armour.

Since the first ironclads were produced with plates of $4\frac{1}{2}''$ the gradual development of artillery fire has led to an increase in the thickness of the armour, and thus to its concentration on the more vital parts, more particularly for the protection of the machinery and the magazines. The other points which have to be considered are the guns, the buoyancy, and the stability; the amount of protection which should be afforded to these by armour is a matter about which there is a great divergence both in theory and practice.

Changes.

The general features of the change may be summed up as follows:—

1. Side armoured middles, and ends protected by an unarmoured water-tight deck below the water-line—type "Warrior."
2. Side armour throughout the water-line with an armoured central battery, type—"Hercules" and "Devastation."

3. Side armoured middles, and ends protected by an armoured deck below the water-line, surmounted by a cellular or raft body, with armour around guns—types "Inflexible," "Duilio"; or without complete gun protection—types "Northampton" and "Baiern."
4. No side armour for the protection of buoyancy or stability, but an armoured deck below the water-line extending from stem to stern and surmounted by a raft body, as in ends of "Inflexible," with armour around the slides and carriages of the heavy guns—type "Italia."

Another development of this type, but altogther smaller and weaker, and without protection for the guns, is the "Comus" class.

The following table, taken from a paper by Admiral Sir Spencer Robinson, K.C.B., F.R.S., shows clearly the gradual change from "Warrior" to "Inflexible:"—

## Table showing Distribution of Armour.

| Ship. | Displacement at Load Draught. | Total Weight of Armour and Backing carried by Ship. | Maximum Thickness of Armour and Backing. On Sides. | Maximum Thickness of Armour and Backing. On Turrets. | Maximum Weight of a Square Foot of Armour and Backing including Skin and Frames. On Sides. | Maximum Weight of a Square Foot of Armour and Backing including Skin and Frames. On Turrets. | Proportion of Displacement to protective Armour. | Approximate Extent of the Protection afforded to the Ship by Armour, with reference to the Waterline and Battery. |
|---|---|---|---|---|---|---|---|---|
| | tons. | tons. | inches. | inches. | lbs. | lbs. | | |
| "Warrior" | 9,210 | 1,354 | $4\frac{1}{2}$, iron<br>18, teak | Nil. | 284 | Nil. | 6·38 | 213 feet of waterline out of 360 feet, extending to $5\frac{1}{2}$ feet under water, and 213 feet of battery. |
| "Minotaur" | 10,690 | 2,106 | $5\frac{1}{2}$, iron<br>10, teak | Nil. | 297 | Nil. | 5·08 | Entirely from stem to stern and over the whole length of battery, about 400 feet. |
| "Bellerophon" | 7,550 | 1,273 | 6, iron<br>10, teak | Nil. | 383 | Nil. | 5·93 | 91 feet of battery, whole of waterline (about 300 feet) to 6 feet below. |
| "Hercules" | 8,680 | 1,949 | 9, iron<br>22, teak | Nil. | 511 | Nil. | 4·45 | 72 feet of central battery, 20 feet battery at extremities, all waterline (about 320 feet) to 6 feet below. |
| "Alexandra" | 9,490 | 2,348 | 12, iron<br>12, teak | Nil. | 645 | Nil. | 4·00 | 75 feet of central battery, 44 feet of upper battery, all waterline (about 320 feet) to 6 feet below. |
| "Glatton" | 4,910 | 1,965 | 14, iron<br>15, teak | 14, iron<br>15, teak | 660 | 700 | 2·50 | 87 feet of breastwork, 1 turret, all waterline (about 240 feet) to 6 feet below at fighting draught. |
| "Devastation" | 9,330 | 2,961 | 12, iron<br>18, teak | 14, iron<br>15, teak | 664 | 726 | 3·15 | 153 feet of breastwork, 2 turrets, all waterline (about 280 feet) to 5 feet below. |
| "Dreadnought" | 10,820 | 3,666 | 14, iron<br>15, teak | 14, iron<br>15, teak | 751 | 726 | 2·95 | 186 feet of breastwork, 2 turrets, all waterline (about 320 feet) to 5 feet 8 inches below. |
| "Inflexible" | 11,400 | 3,558 | 24, iron<br>17, teak | 16, iron and steel<br>18 teak | 1,150 | 802 | 3·26 | 110 feet of breastwork, 2 turrets, and 110 feet of waterline out of about 320 feet are defended by side armour; the remainder of waterline is protected by an armoured water-tight deck below the water. |

**Note.—All the above are seagoing ships, except the "Glatton," ship for attack and defence of coasts.**

In dealing with the different classes of ships, space will only allow of short descriptions and diagrams of one or two prominent types.

## Armoured Ships.

**Armoured ships.**

**Classification.** These ships have recently been classified as follows in our service:—

Battle ships, containing all the more powerful sea-going ironclads.

Cruisers, comprising the belted ships and a certain number of the older broadside ironclads.

Special ships, being those specially designed for ramming, and a few others.

Ships for attack and defence of coasts, including the ships formerly designated "Coast Defence" ships.

For descriptive purposes, however, armoured ships will be divided into:—

Seagoing armoured ships.

Ships for attack and defence of coasts.

Seagoing armoured ships again may be classified according to their distinctive features, in the following order, which is that, roughly speaking, in which they were produced:—

1. Broadside ships of the old type.
2. Central battery ships.
3. Turret ships.
4. Belted ships with partially unarmoured batteries.

The *barbette* system may be employed with either 1, 2, or 4, so need not be considered separately.

### 1. *Broadside Ships.*

**Broadside.** This class of vessel being virtually obsolete calls for no special remark.

The protected battery either extended the whole length of the ship, or was long and combined with armoured bulkheads, and in most ships of the class the whole of the water-line was protected by side armour.

The "Minotaur" may be taken as an example.

As stated above, some of the older ships of this type are now classed as "Cruisers."

### 2. *Central Battery Ships.*

**Central battery.** In this class the necessity for carrying thicker armour led to its concentration on the waterline and on a smaller battery,

ral ry. thus forming what are known as the central or box battery ships.

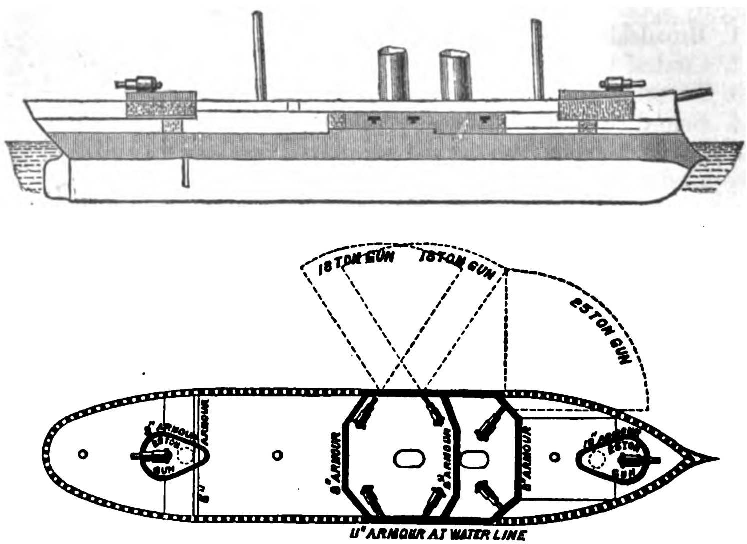
Recessed sides were also introduced to give fore and aft fire, and the protected battery on the main deck is supplemented in various ships by (*a*) barbette towers; (*b*) a protected upper deck battery; (*c*) guns mounted at the extremities of the ships.

The armour on the battery is, as a rule, thinner than that at the waterline amidships, and this again usually tapers towards the bow and stern, and below the waterline. An armoured deck is frequently added outside the central fort, as a protection against curved or depressed fire.

This class contains by far the greater number of what are now considered as battle ships, though in our navy a few of the smaller vessels are ranked as "special ships." The vessels composing it are usually masted, and having good accommodation, are very valuable for service on foreign stations.

éméraire." The "*Téméraire*" may be taken as one of the newest examples of this class of ship, and is the only representative of the barbette system in the English navy

Téméraire.




The side armour extends round the ship from below the waterline to the main deck, being carried down forward over the ram.

The central battery extends as high as the upper deck, and is divided into two parts by a transverse armoured bulkhead. "Téméraire."

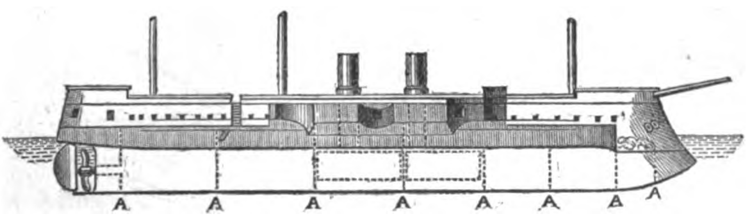
Outside the battery the part above the belt of armour is protected by an armoured deck, and further by a 5″ to 3″ iron bulkhead across the hold, which preserves the magazines and vital parts of the ship from raking fire.

On the upper deck at each end is an armoured pear-shaped tower, standing about 6′ above the deck; this is connected with the lower protected part of the ship by an armoured trunk, and contains a revolving platform on which is mounted an 11-inch gun, worked by hydraulic power on the disappearing principle.

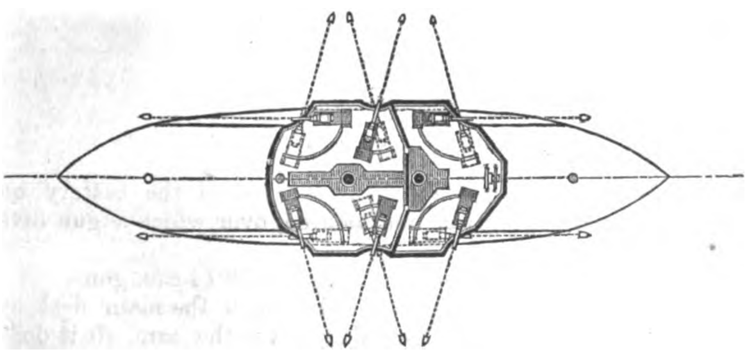
These guns have a complete view round each end of the ship, firing over low bulwarks.

"*Tegetthoff*" (Austrian). "Tegetthoff."

TEGETTHOFF (AUSTRIA).




A. A. Water-tight bulkheads.



In this ship the armament is confined to the main deck, the battery projects considerably over the sides of the ship, and the arrangement of ports is peculiar.

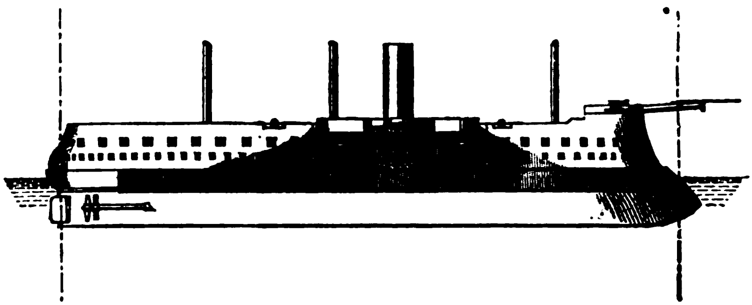
The sail power is small.

"Dévastation."

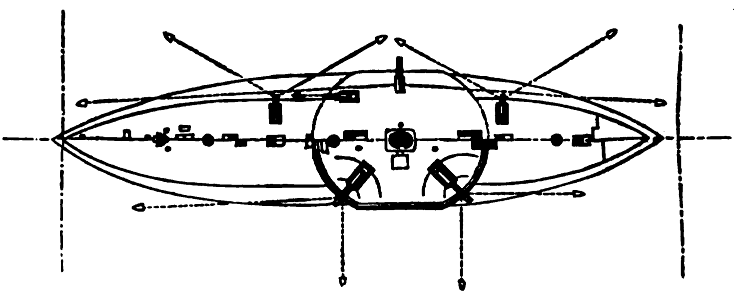
"*Dévastation*" (French).

This ship has an overhanging central battery with the ends of the ship deeply recessed, a heavy gun being mounted in

DÉVASTATION (FRANCE).



Upper Deck.



Main Deck.

each corner of the battery. On the top of the battery on each side is a half tower unarmoured, over which a gun fires *en barbette.*

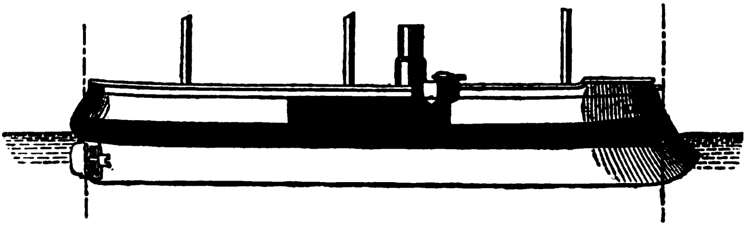
There is also an unprotected battery of 8·14 c.m. guns.

The belt of armour does not quite reach the main deck at the ends; forward it is carried down over the ram, aft it does not quite reach the stern.

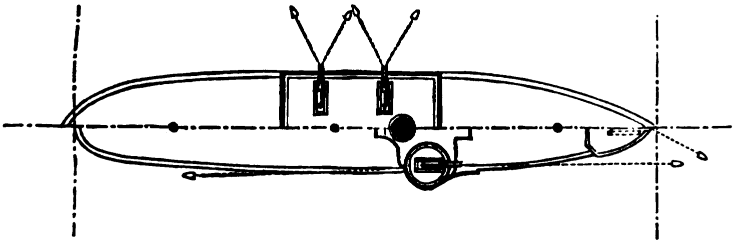
It was found necessary to give 64′ interior space in the battery, in order to be able to work the heavy guns (34 c.m. or 46 tons) carried. These are the heaviest which it is at present proposed to mount on the broadside of any ship.

"*Victorieuse*" (French), is an example of a smaller class with "Victorieuse."
a projecting tower on each side above the battery.

VICTORIEUSE (FRANCE).



Main Deck.

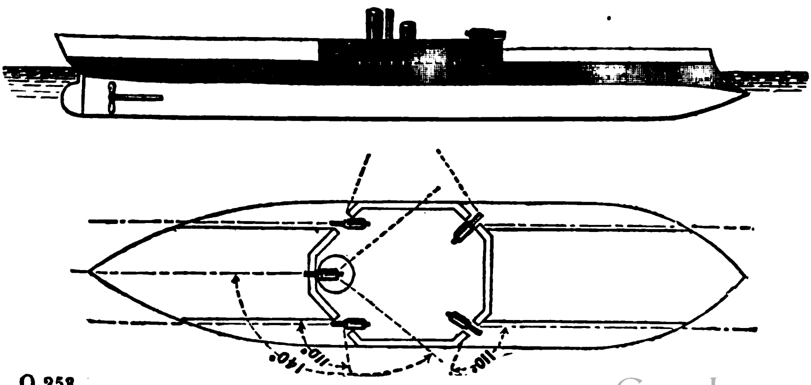


Upper Deck.

The guns in these towers have a complete sweep fore and aft, but the battery guns have only broadside fire. There is a gun under the forecastle giving end on fire, and six guns of 14 c. m. are also mounted on the upper deck.

"*Heligoland*" (Danish), has a central battery and recessed "Heligoland."
sides, but in addition carries amidships on the top of the fore end of the battery a revolving unarmoured tower with one heavy gun *en barbette*.

HELIGOLAND (DENMARK).





 U

### 3. *Turret Ships.*

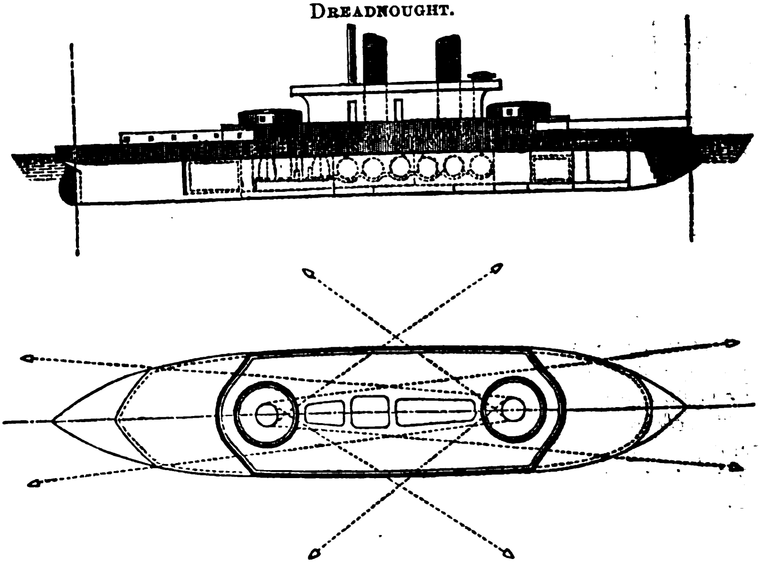
Omitting the "Monarch" type as exceptional, all sea-going turret ships now belong to the breastwork or citadel type, that is, there is an armoured citadel built on the low free board hull and containing the bases of turrets, with machinery for working (and loading in some cases) the guns.

In the first ships which were built of this type the ends were protected by armour, but the later examples have all the side armour concentrated on the citadel and turrets.

"Dread-nought."

The "*Dreadnought*" may be taken as the latest example of the former type.

DREADNOUGHT.



In this ship the side armour at the ends is of a uniform height of 4′ above the water and is covered by a $2\frac{1}{2}''$ armoured deck, increased to 3″ at bow and stern. The citadel is brought out to the sides of the ship and rises to a height of 12′ above the water, being 184′ long, and it is covered by a 2″ armoured deck, increased to $2\frac{1}{2}''$ round turrets. At each end of the citadel is a revolving turret containing two guns worked by hydraulic machinery.

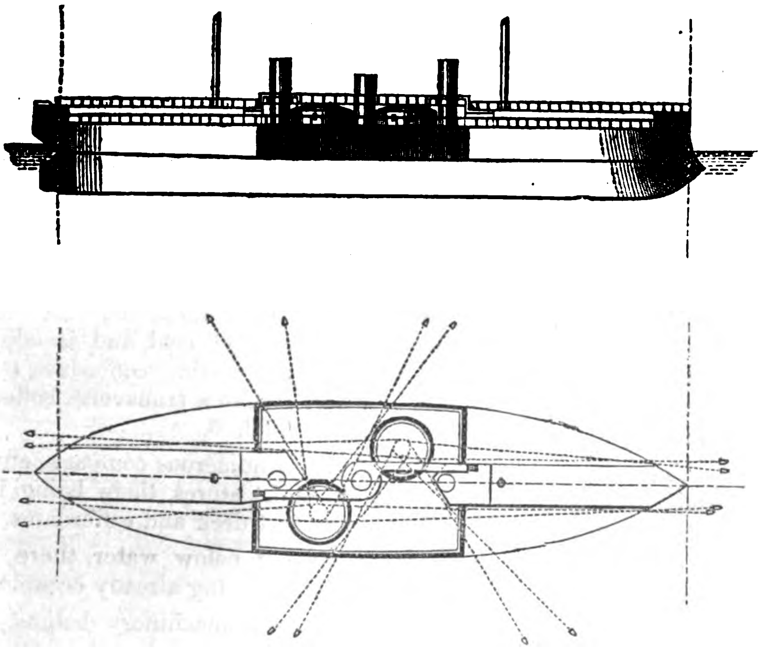
On the citadel amidships between the turrets is a flying deck for purposes of navigation, &c., and at each end of the ship there is built on to the ends of the hull proper a light iron structure rising about 10′ out of the water.

These ships are not rigged.

The only first class ship of this type, in any foreign navy, is the "*Peter the Great*" (Russian).

The "*Inflexible*" is an example of the class of turret ships with unarmoured ends. This class is at present confined to the English and Italian navies. "Inflexible."

INFLEXIBLE.



In the "Inflexible" the citadel is 110′ long and 75′ wide, rising to a height of 10′ above the waterline, and is covered by an armoured 3″ deck.

On this citadel are placed *diagonally* the two turrets. The side armour of citadel is carried to a depth of $7\frac{1}{2}$′ below the fighting waterline. The armour is in two thicknesses, the outer of 12″ on a teak backing of 11″ and the inner of 12″ at water line, 8″ above, and 4″ below, also supported by backing.

The armour on the fore bulkhead is similar, but that on the after bulkhead is thinner, while that on the turrets is 17″ round ports and 16″ elsewhere.

Inflexible.

At a depth of 6 to 7 feet below the water is a submerged hull on which the citadel is built. It has a powerful ram, low submerged rudder and helm, and the deck is covered from the citadel to the ends with 3″ armour, which forward is carried down to the ram.

This submerged hull with citadel and turrets contains the vital portions of the ship, and is divided into a large number of watertight compartments.

On this hull proper there is at each end a light unarmoured structure rising 20′ out of the water from stem to stern, but the upper part is recessed to allow of right ahead and astern fire from the guns.

As these ends are liable to injury from shell fire, every precaution is taken to minimise its effect, and to prevent in such case the inflow of a large quantity of water, as this would considerably lessen the speed and stability.

For this purpose there is a second watertight deck a little above the waterline, and the space between this and the armoured deck below it is again divided at each end into two principal parts. The part next to the citadel, about 50 feet long, is entirely devoted to the stowage of coal, and is additionally protected on the outside by a double cofferdam, the outer one filled with cork. There is also a transverse cofferdam at the end farthest from the citadel.

The extremes are subdivided into numerous compartments and are used for the stowage of bulky stores, there being in addition at the bow another watertight deck and cofferdams.

By these means, even if penetrated below water, there is little room for water, most of the space being already occupied.

The guns are loaded by hydraulic machinery behind a glacis on the citadel deck, so that increased length may be given to them.

She is rigged lightly for service in time of peace.

"Ajax."

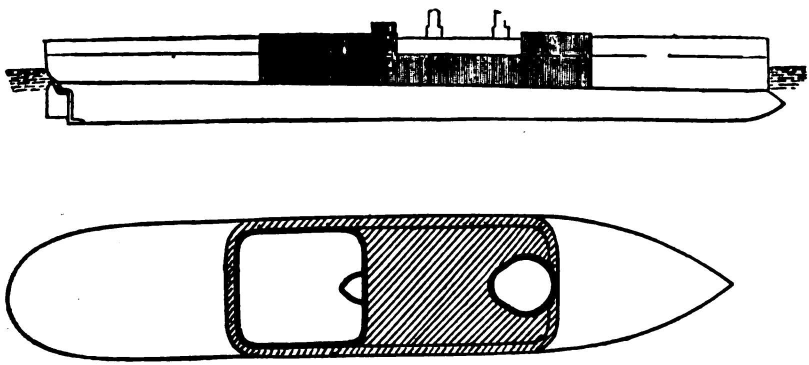
The "Ajax" "Colossus" types are similar in design but smaller, and are not rigged.

"Duilio" class.

The "Duilio" and "Dandolo" (Italian) are similar in design; the only important modification being that the part between the watertight decks, outside the citadel is divided into a large number of small empty cells instead of being occupied by coal and stores. If many of these cells were so perforated as to admit water it is believed that the stability could be seriously diminished.

"*Baiern*" (German) approaches in design to a citadel turret ship with unarmoured ends, such as the "Inflexible." The guns, however, are mounted in fixed barbette batteries on top of the citadel, as will be seen from the diagram; the foremost tower is pear-shaped, and carries two heavy guns, whilst the after battery has a gun at each corner, and a conning tower at the foremost end. "Baiern."

BAIERN (GERMANY).



The citadel and towers are heavily armoured, and outside the citadel the ends of the ship are protected by a submerged armoured deck and a raft body, above which are unarmoured structures rising to the level of the citadel.

### 4. *Belted Ships.*

This class is a small one, being confined to three ships in the English navy, three in the Russian, and one in the French. Belted ships.

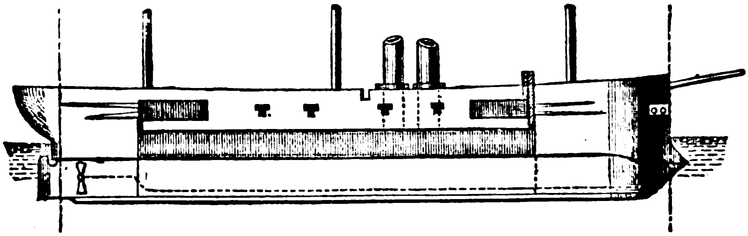
The ships composing it have the armour concentrated on the waterline, the battery being unprotected or partly so, as a rule are full rigged, and in our navy are classed as "Cruisers."

The side is specially constructed to avoid splintering and to offer small resistance to the passage of a projectile, the guns are far apart, and in some cases a system of traverses and mantlets is applied.

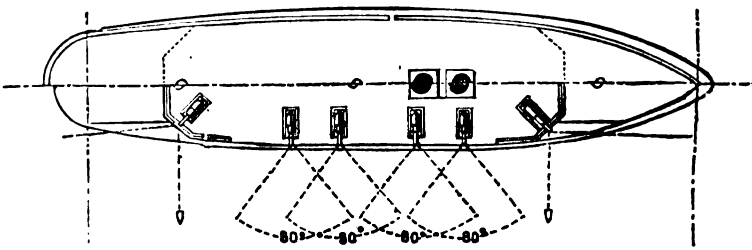
"Northampton."

The "*Northampton*" is an example.

NORTHAMPTON.



Upper Deck.




Main Deck

This ship is protected by a belt of armour amidships, about 180′ in length, and extending from 4′ above the water-line to 5′ below it.

Across each end of this belt is an armoured bulkhead extending from the bottom of the belt to the upper deck, being 22′ in height. Between the main and upper decks this belt is shaped as shown in the sketch to form corner ports at the fore and after ends of the battery, and is also carried a little distance along the side of the battery.

Between the bulkheads and at the upper level of the armour belt is a 2″ armoured deck, and before and abaft the bulkheads, 5′ under water, there is a 3″ armoured deck extending to the ends of the ship, and at the bow brought down to the ram. These decks are intended to preserve from injury the lower parts of the ship.

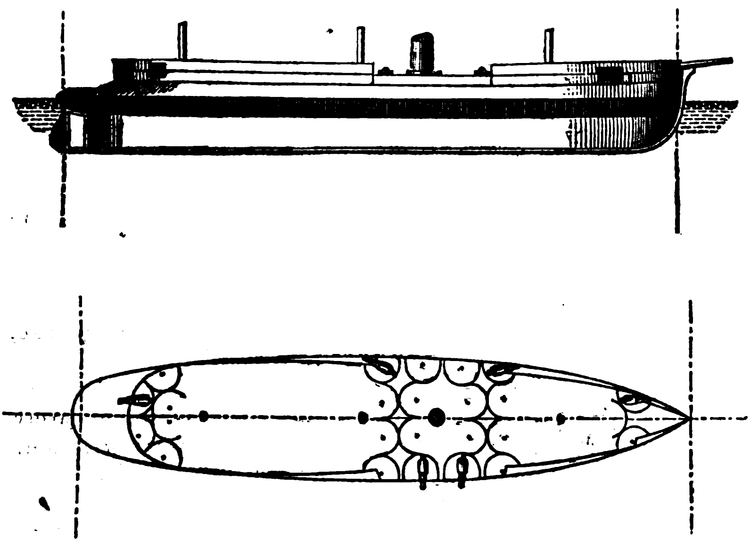
The armament consists of four 10-inch and eight 9-inch guns, all mounted on the main deck, as shown in the sketch. Northampton.

The intermediate 9-inch guns are completely unprotected, but a system of traverses and heavy mantlets is provided, intended to confine any explosion or injury as much as possible.

This broadside of guns is intended to be laid in close engagement under shelter of the bow or stern armour and then fired by electricity, exposing the crews as little as possible.

The "*General Admiral*" (Russian), is of a different design. "General Admiral."

GENERAL ADMIRAL (RUSSIA).



All the guns can be fought on one side.

The waterline belt extends from bow to stern, from 4′ above to 3′ below the waterline, and the decks are lightly plated.

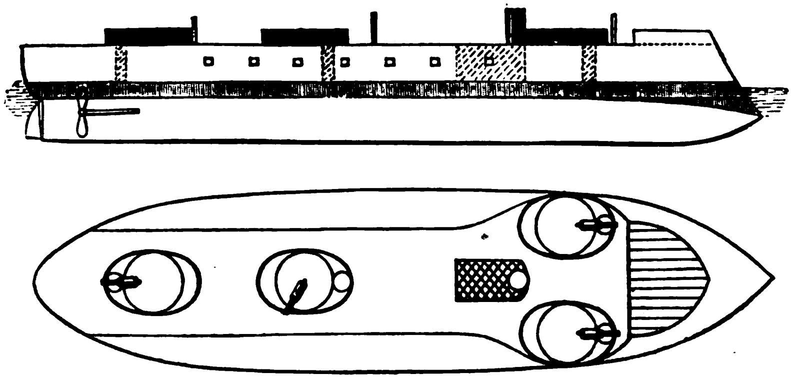
There are no bulkheads as in the "Northampton," the battery is on the upper deck and projects so as to give fore and aft fire to the corner guns without recessing the sides. The guns are unprotected by armour.

This ship has a large coal supply, and is designed for a high rate of speed.

"Admiral Duperré."

The "*Admiral Duperré*" (French), is a vessel of peculiar type. She has a waterline belt of heavy armour and above this is an unarmoured structure of high freeboard, and carrying four fixed armoured barbette towers placed as shown in diagram.

ADMIRAL DUPERRÉ (FRANCE).



These are connected by small armoured trunks with the protected part below; the bases of the funnels are also protected by a trunk. There is also an unprotected battery of light guns.

She is very heavily armoured and armed, is of large size, and is to be full rigged.

The "*Italia*" and "*Lepanto*" (Italian), are ships in which as stated above the side armour has been entirely suppressed, the raft body and armoured underwater deck being substituted.

There is an armoured barbette oval in form and placed diagonally across the centre part of the ship, at each end of this is a revolving platform carrying two 100-ton guns. There is also to be a secondary armament of eighteen 6-inch B.L. guns.

### SHIPS FOR ATTACK AND DEFENCE OF COASTS.

Ships for attack and defence of coasts.

These may be classed as follows:—

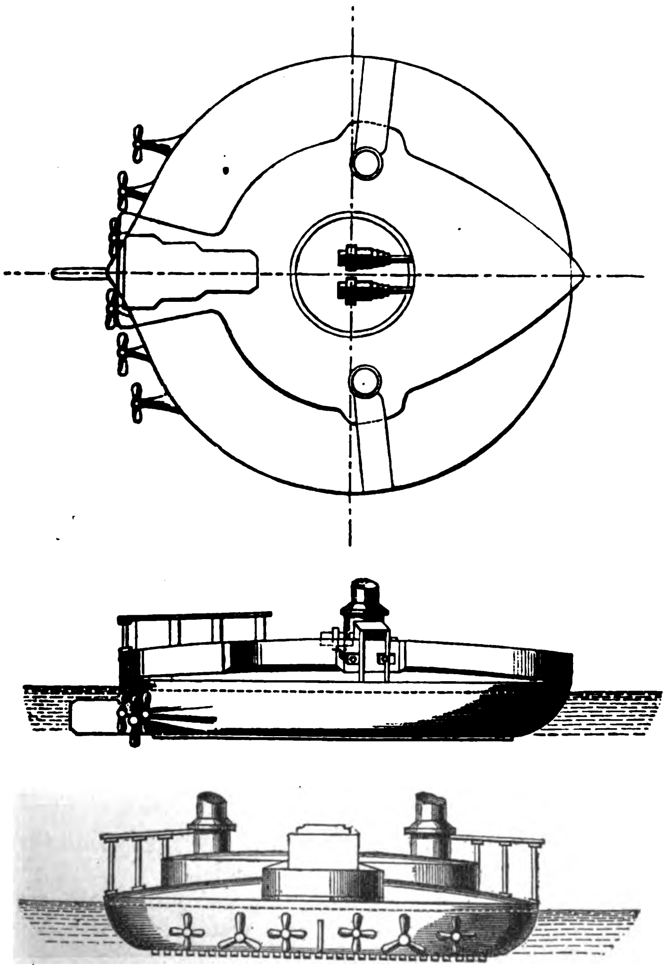
(*a.*) Floating forts such as the "Popoffkas."
(*b.*) Turret ships and rams.
(*c.*) Gunboats, armoured.
(*d.*) Small armoured vessels of light draught specially designed for service in lakes and rivers.

Some of these vessels are possessed of fair seagoing qualities but are not designed for long cruises. They would, however, under favourable circumstances, be available for the attack as well as the defence of a coast.

## (a.) *Floating Forts.*

"*Admiral Popoff*" (Russian), and the "Novgorod," somewhat smaller, make up this class, no other nation having adopted the design. Floating forts: "Admiral Popoff."

ADMIRAL POPOFF (RUSSIA).



miral Popoff.

They are deficient in speed and manœuvring powers, owing to their circular form, but from their light draught of water and formidable armour and armament they are well adapted for movable forts.

They are circular in section, have a curved and armoured deck, and a fixed tower in the centre, in which the guns are mounted *en barbette* on a revolving platform.

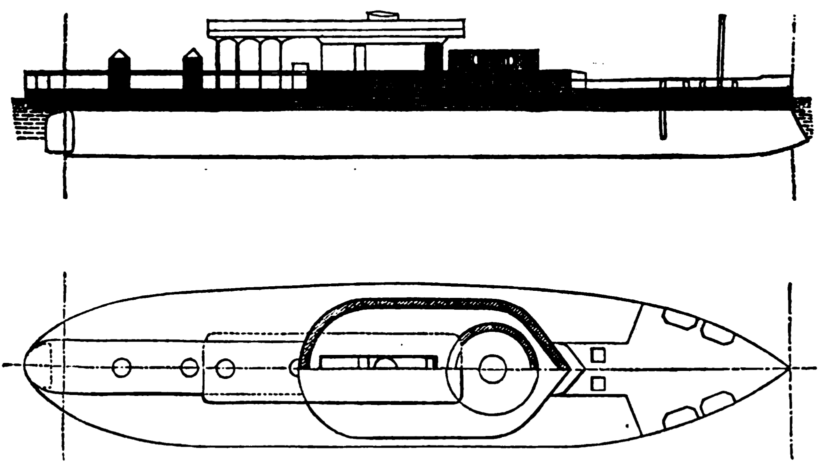
The guns in the "Admiral Popoff" are worked by hydraulic machinery on the disappearing principle. The tower is 13′ above the water-line, and the edge of the upper deck 1½′. The armour extends to 4½′ below the water. The hull is divided into many compartments.

## (*b*.) *Turret Ships and Rams.*

urret ships: Glatton."

The "*Glatton*" may be taken as an example of a large turret ship of this class of the citadel type.

GLATTON.



As will be seen from the diagram there is only one turret, and this is placed on the fore part of citadel.

The freeboard is 3′ for cruising, but on going into action can be reduced to 2′ by admitting water into the double bottom.

The side armour extends from the upper deck to 5′ below the water when going into action. It is 12″ thick in the upper strake and 10″ in the lower, and this thickness is kept up to within about 20′ of each end, where it is tapered. Glatton.

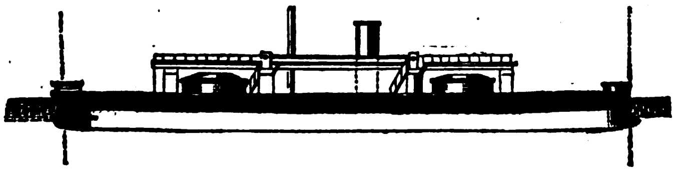
The deck before and abaft the breastwork is protected by 3″ armour, and that on the top by 1½″.

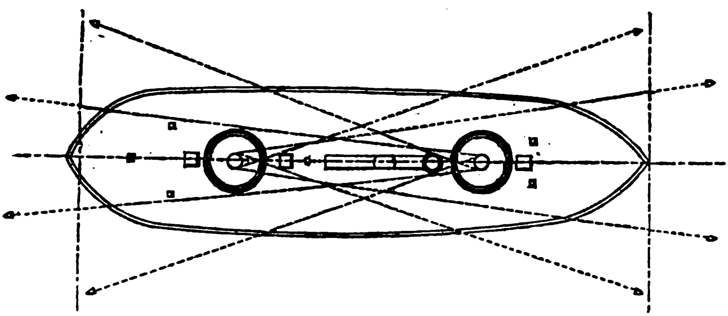
The citadel rises to a height of 6′ 3″ above the deck and is armoured.

The turret armour is 14″ by the ports and 12″ elsewhere. The guns are mounted far enough apart to be able to fire right aft, one on each side of the superstructure, so that the one turret has an all round fire.

The "*Solimoes*" (Brazil), is an example of a turret ship without a citadel. She has two revolving turrets, the freeboard is 2½′, and the side armour goes to a depth of 2′ below waterline, and tapers from 12″ amidships to 6″ at the ends. The draught of water is small, and the deck is protected by horizontal armour. "Solimoes."

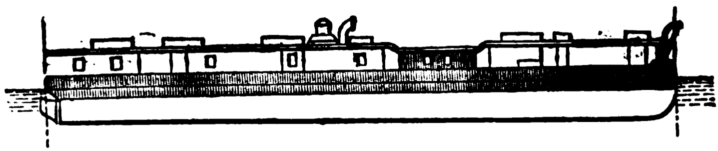
SOLIMOES (BRAZIL).

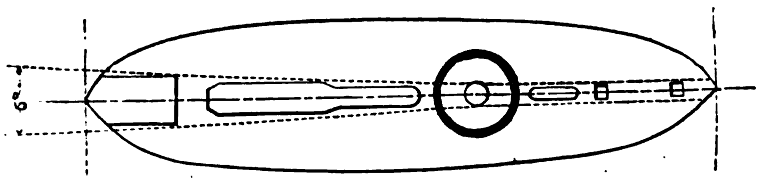




The "*Krokodil*" (Holland) is of the same type, but has only one turret, the stern fire of which is a little hindered by light erections in the middle line of the deck. The armour belt is 5′ wide, and the draught of water is very light.

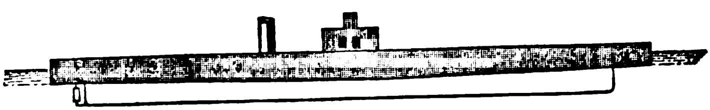
KROKODIL (HOLLAND).






"Brononosetz." The "*Brononosetz*" (Russian) has one revolving turret in the centre of the vessel. The draught of water and speed are small, the deck is not armoured, there are no erections on the upper deck, and the freeboard is about 18″.

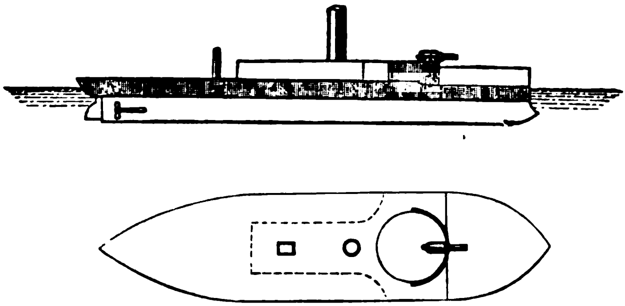
BRONONOSETZ (RUSSIA).



As will be seen by the diagram, the armoured part of the hull projects considerably over the lower portion.

The "*Biene*" (German) represents a different class of ship, being specially designed for end-on fire. The deck is armoured, and carries a fixed tower armoured towards the bow, and containing one gun *en barbette*. There are light erections on the armoured deck, but they are kept below the level of the gun. Speed is fair and draught of water small. "Biene."

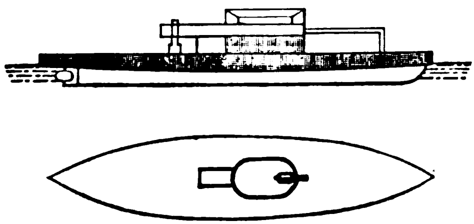
BIENE (GERMANY).



## (c.) *Gunboats, armoured.*

The "*Berserk*" (Sweden) may be taken as an example of an armoured gunboat. Gunboats: "Berserk."

BERSERK (SWEDEN).



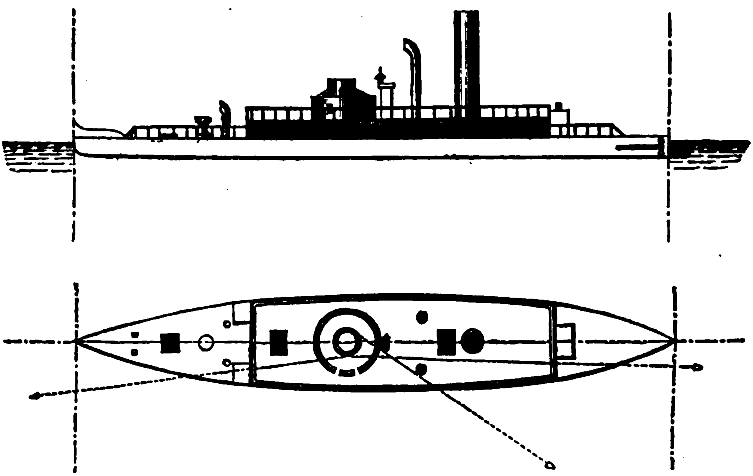
She is of small tonnage (460), and of light draught of water, with a freeboard of about 1′. Being designed for right ahead fire the turret is fixed, and both the turret and fore part of the ship are much more heavily armoured than the beam and after part; the armour on the turret being 14″ in front and only 3″ in rear, and the side armour tapering from 6″ forward to 2″ amidships.

### (d.) *Armoured Vessels for River and Lake Service.*

River and lake: "Rhein."

The "*Rhein*" (German), is a small vessel of very light draught and low freeboard, the hull being unprotected by armour. On this hull is built a citadel about 5′ above the

RHEIN (GERMANY).



water-line. It is plated with 2″ plates, and has $\frac{1}{16}$″ plating on its deck.

On this citadel is a revolving turret similarly protected, containing two guns, and carrying a pilot tower on top.

## UNARMOURED SHIPS.

Unarmoured ships.

Classes.

These ships are divided in our service into the following principal classes :—

1. Cruisers, 1st, 2nd, and 3rd class.
2. Sloops.
3. Gun vessels.
4. Gunboats, 1st class, for general service.
   ,, for attack and defence of coasts.
5. Despatch vessels.
6. Torpedo vessels and boats.

The classes comprising cruisers, sloops, gun vessels and 1st class gunboats run almost imperceptibly into each other, and are not capable of any exact definition.

"Comus" class.

No attempt will be made to give descriptions of the very large number of different types which exist, but the "Comus" class may be specially mentioned, as these vessels, though here classed as unarmoured cruisers, in reality approach nearly in some of their characteristics to the latest designs of ironclads.

In these ships there is a water-tight deck $3\frac{1}{2}$ feet below the water-line, over the engines and magazines protected by $1\frac{1}{2}$ inch steel plating, and above this is a cellular raft body, covered by a second water-tight deck.

By this means the more vital parts of the ship are well protected, and these vessels would have a great advantage in action with the ordinary type of unprotected cruiser.

## *Gunboats for Attack and Defence of Coasts.*

Gunboats for attack and defence of coasts. "Gamma."

The "*Gamma*" (Chinese, built in England) is the most powerful type of unarmoured gunboat of this class. Her dimensions are—

| | |
|---|---|
| Length - - - - | 126′ |
| Beam - - - - | 30′ |
| Draught of water - - | 8′ |
| Displacement - - - | 400 tons. |

She is schooner rigged with tripod masts, carries 50 tons of coal and 50 rounds of ammunition, and has fair seagoing qualities and a speed of 9 knots.

The armament consists of one 38-ton M.L. gun.
" " two 12-prs.
" " one Gatling.

The heavy gun has right ahead fire only, the training being got on by the movement of the boat.

It is worked entirely by hydraulic power.

"Comet."

The "*Comet*" class is smaller and specially intended for coast defence.

Dimensions:—

| | |
|---|---|
| Length - - - - | 85 feet. |
| Beam - - - - | 26 " . |
| Draught of water - - | 5·9 " <br> 6·3 " |
| Displacement - - - | 254 tons. |
| I.H.P. - - - - | 262 |
| Speed - - - - | 8½ knots. |

The armament is one 10-inch M.L.R. gun ; it is mounted forward for end-on fire, and has a little training. It is so arranged that while at sea it can, together with its platform, be kept near the bottom of the ship, being raised to the level of the deck when preparing for action.

*Despatch Vessels.*

Despatch vessels.

The steel vessels "Iris" and "Mercury," together with some smaller vessels, are classed by themselves.

*Torpedo Vessels and Boats.*

Torpedo vessels.

These require no special description. They may be divided into torpedo vessels proper, first class torpedo boats and second class torpedo boats, the latter being also carried by seagoing ships.

| Torpedo Boats. | First Class. | Second Class. |
|---|---|---|
| Length - - - | 86′ 3″ | 60′ 4″ |
| Beam - - - - | 10′ 9″ | 7′ 6″ |
| Draught of water - - | 1′ 7″ <br> 5′ 0″ | 1′ 3½″ <br> 3′ 4″ |
| Displacement - - - | 32 tons | 10·6 tons. |
| Speed - - - | 18 to 20 knots. | 16 knots. |

# CHAPTER XVI.

## ARMOUR.

In this chapter will be described the different kinds of armour used for the protection of ships and of land defences, treated merely as regards the actual resistance to projectiles, and in the case of ships, to the weight carried and the structural necessities involved. No reference will be made to the position of the armour on the ship, as this has been shortly alluded to in chapter XV. Subject.

The subject will be treated under two heads:— Heads.

1. Ships.
2. Land Defences.

Under the former head will be mentioned, first, the different methods of placing the armour; secondly, the material of which it is composed; and, finally, experiments with various special targets.

### I. Ships. Ships.

*Forms of Armour.*

The original ironclads, as stated in the chapter on ships, had $4\frac{1}{2}''$ of wrought-iron armour; this was bolted on to a simple wood backing, which again was fastened to an inner skin. Since that period the thickness of armour has been very much increased, the backing has been strengthened and rendered more rigid by working in iron stringers of various forms, the material has been in some cases changed to steel or steel-faced iron, and the armour has sometimes been put on in two or more thicknesses with backing between. Development of armour.

Some special forms of armour have also been devised, and will be mentioned.

Armour may be considered, as regards ships, to consist of four parts: Parts.

1. The armour plates.
2. The fastenings by which it is secured to the body of the ship.
3. The backing, simple or compound.
4. The inner skin, and frames.

The armour proper is intended to stop and break up projectiles, and, as originally constructed (of wrought iron), depended entirely on its toughness, being very soft. Armour plates.

In the armour, however, more recently introduced, and constructed wholly or partially of steel, the hardness of the material is a principal factor in the amount of resistance offered.

Fastenings.

The fastenings have an important bearing on the value of a plate against penetration. They should be very strong; of small size, as if too large they would weaken the plate, but at the same time large enough to enable a comparatively small number to be effective; and they must have a certain amount of elasticity, to withstand the violent shock produced by the blow of a projectile.

Backing.

The backing should have a certain amount of rigidity to assist in supporting the plate locally, but must be at the same time elastic, so as to deaden the effect of a blow on the whole structure.

Skin and frames.

The skin should be as tough as possible, to support the whole structure, and to stop splinters and pieces of projectiles which may perforate the armour plate, and must be well supported by the frames.

Types.

Considering the various types of ship armour, we have—

Original.

(*a.*) A wrought iron plate in one thickness, with plain wood backing and inner skin. This form is now never adopted, as it was found that the simple wood backing, though it deadened the blow, had not sufficient rigidity to support the plate, which was penetrated almost as easily as if it were unbacked.

Stringer backing.

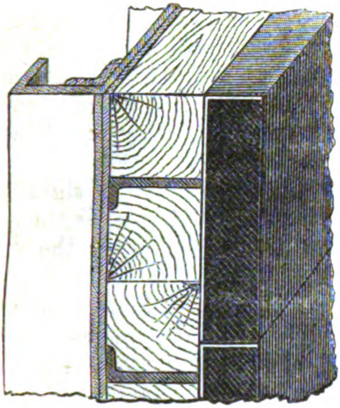
(*b.*) A similar plate, backing, and skin, but with stringers of wrought-iron placed edgeways, worked horizontally into the wood backing, the front edges being kept just clear of the back of the plate. This system was found to give great rigidity to the backing, and considerable support to the plate, and since the "Bellerophon," has been generally used in the English navy. (*See* diagrams, p. 323.)

U stringers.

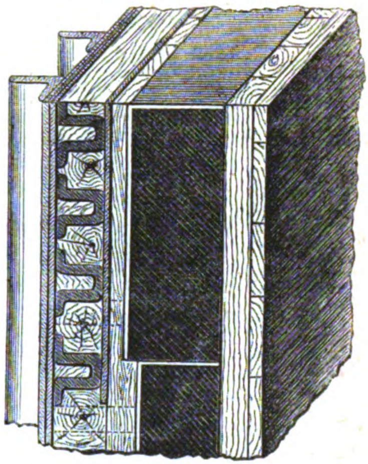
(*c.*) The same as the above, but with the stringers made U-shaped and considerably heavier. This system of backing was invented by Mr. Hughes, and in applying it he uses, when practicable, two thicknesses of stringers, one being vertical and the other horizontal.

It is claimed for this system, but is not generally admitted, that a greater power of resistance is obtained for the total weight of armour and backing than if the plain stringers and thicker plates were used.

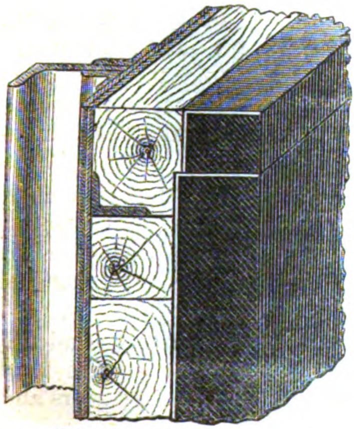
This form of backing gave very good results with the Millwall shield experimented on some years ago, but has not been generally adopted; some ships in the Russian navy being, as



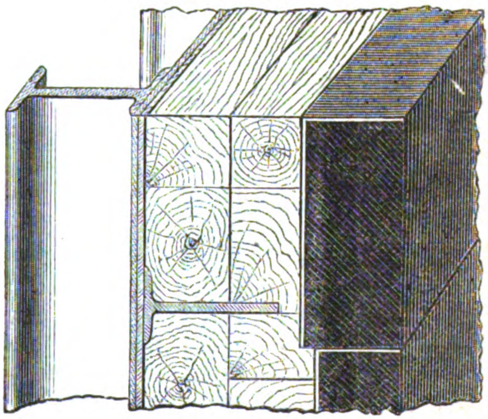

BELLEROPHON. 1862.



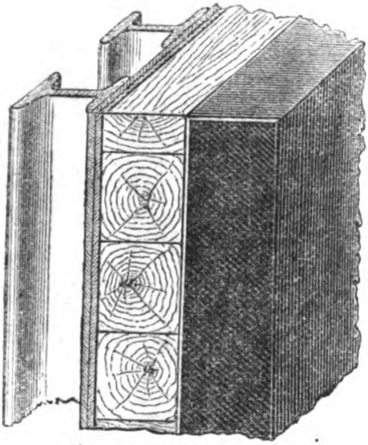

PETER THE GREAT (RUSSIA). 1871.




TÉMÉRAIRE. 1873.

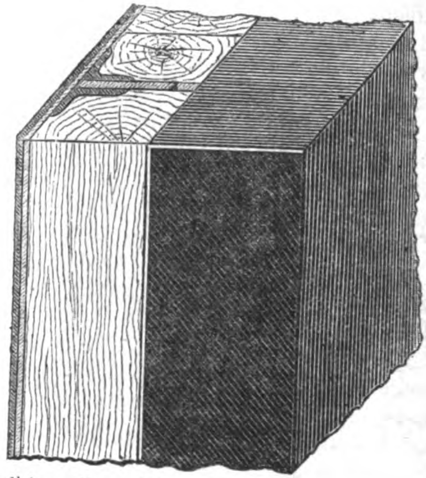



TONNÈRE (FRANCE). 1873.



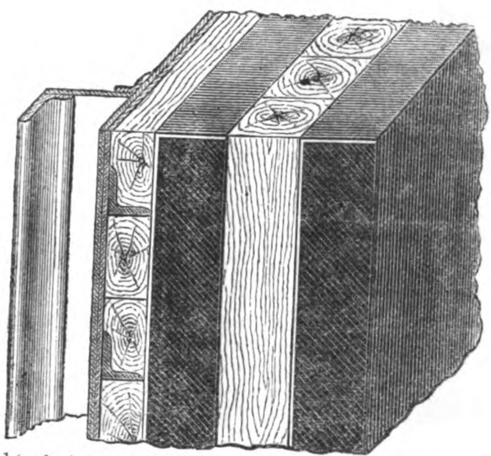
1½ <....15....> <....15. ..>

DÉVASTATION (FRANCE). 1876.



1½ <.......18.......> <.........22........>

DANDOLO (ITALIAN). 1876.



1 <...6...> <..12...> <...11...> <...12...>

INFLEXIBLE. 1876.

far as is known, the only examples. (*See* diagram, "Peter the Great," p. 323.)

(*d.*) What is known as the sandwich target. Here the armour plate is in two thicknesses, as in the case of the "Inflexible" target, with a layer of backing between the two plates, and an internal backing strengthened with stringers. (*See* diagram, p. 324.) **Sandwich.**

The advantages claimed for this method of distributing the armour are that, owing to the difficulty of manufacturing a very thick plate, the two thinner plates will probably be of better quality than one thick one of equal weight; the joints of the plates can be broken, thus avoiding to a certain extent a great source of weakness in armour; and the outer plate tends to break up the projectile, thus lessening the effect on the inner plate.

There is also a distinct advantage in the increased depth of target obtained by this method of arranging armour, as the distance through which the projetcile has to do work is considerably increased, and consequently the energy required for perforation must be greater.

The introduction of steel and steel-faced armour will, however, probably modify the above conclusions, especially as after the experiments at Spezzia the Italian Commission pronounced decidedly in favour of single plates.

The above four systems represent the general arrangement of armour for the defence of a ship.

Besides the plain forms of plate, Sir J. Whitworth has introduced two descriptions of armour which have not as yet been tried on a ship, but have been experimented with. **Whitworth special forms.**

The first consists of a steel plate, having secured into its face, at intervals of 3½″, very hard steel studs of 2½″ diameter, intended to break up the projectile. The holes were made to prevent the spreading of the cracks which usually occur in hard steel plates, and advantage was taken of them to screw in the studs. The second was of concentric screwed rings of steel fastened by a central screw to a flat plate of iron.

Both of these gave extremely good results, but there are many drawbacks to the practical adoption of either system.

## *Materials for Plates.*

Having considered the general arrangement of armour and backing, we now come to the material of which armour for a ship should be composed. Rejecting the Whitworth **Materials of armour plates.**

special targets, the materials of which an armour-plate may be composed are—

1. Wrought iron.
2. Steel.
3. Compound, consisting of a steel front run on to a wrought-iron back, so as to form one plate.

Chilled iron, though giving very good results for the defence of land fortifications, requires too great a weight of armour to be suitable for naval purposes.

Wrought iron. (1.) Wrought iron was adopted for armour plates in consequence of its toughness, and because the manufacture of steel was not at that period so fully developed as it is now.

Owing to its softness, though easily penetrated when compared with steel, the destructive effect is only local, that is, supposing the plate to be good, a hole is punched or an indentation is made without much injuring the surrounding parts. This is, of course, a great advantage in the event of a plate being struck by more than one projectile in the same vicinity.

Steel. (2.) Steel, on the other hand, though by its excessive hardness it breaks up the projectile and resists penetration to a much greater extent than wrought iron, is found to be affected by a blow over a great extent, and the deductions from the Spezzia experiments may be considered to be, that, with right-angled impact, steel has a much greater power of resistance to the attack of a very powerful projectile than wrought iron, but that if exposed to the continued fire of lighter guns the defences would soon be completely ruined; while a wrought-iron plate which would be penetrated by the heavy, would resist a large number of light projectiles without much injury.

Steel, however, if the impact be oblique, has a still greater power of resistance, as the hard face causes the projectile to glance.

Compound. (3.) Compound armour possesses the advantages of both wrought iron and steel, and very successful results have been obtained with targets of this material.

The steel face, being excessively hard, breaks up the projectile or causes it to glance if struck obliquely, whilst the tough iron to which it is welded keeps the steel from the excessive cracking to which it is liable if used alone.

Mr. Barnaby, in a paper read before the Institute of Naval Architects, states that at the late Paris Exhibition Messrs. Cammell and Messrs. Brown both exhibited the comparative effects of fire from a 7-inch gun at 70 yards range against wrought-iron and compound 9″ plates. The results were :—

*Messrs. Brown.*

Compound.

| | | Charge of powder. | |
|---|---|---|---|
| Iron plate | - | 25 lbs. | Indented 8″ without cracking. |
| Compound (half steel, half iron). | - | 30 lbs. | Indented 4¾″ without cracking. |

*Messrs. Cammell.*

| | | | |
|---|---|---|---|
| Iron plate | - | 30 lbs. | Perforated without cracking. |
| Compound (5″ steel, 4″ iron). | - | 30 lbs. | Indented 3″·12, and cracked from hole to one edge to depth of ⅛″; crack did not go through the iron. |

The turret of the "Inflexible" is to be made of this description of armour, and the conditions laid down are that a piece 6′ long cut off the bent part of the turret and secured to the backing shall neither be perforated nor cracked through by a shot which would penetrate a similar iron target, and that if the edges are supported by a frame no one of three such shots planted at 2′ intervals shall get through.

*Fastenings.*

Fastenings: For wrought iron armour.

Wrought-iron armour is fastened to the framing of the ship by means of large through bolts. The heads of these bolts are coned, and the outer part of the hole in the plate is also coned, so that when screwed home the head shall fit accurately in the plate.

The inner end of the bolt is screwed, and after traversing the inner skin passes through a cup-shaped washer, the convex side of which is towards the skin. This cup is filled with india-rubber, and over this is another washer and a nut, both of which are slightly smaller than the interior diameter of the cup.

When the nut is screwed up tight the elasticity of the india-rubber lessens the jar on the bolt which is caused by a shot striking the plate. The shank of the bolt is slightly reduced in size, so that the screwed part of the bolt shall not be the weakest.

| | | | |
|---|---|---|---|
| The sizes used are | - | 4″ to 5″ armour, | 2″ bolt. |
| „ | - | 8″ to 9″ „ | 3″ „ |
| „ | - | 12″ to 13″ „ | 4″ „ |

For compound armour.

Compound armour is secured in a different manner, in order to avoid the holes made by a through bolt. The head of the bolt is screwed from the interior about half way into the plate; the remainder is similar to the bolt described above.

TABLE showing Comparative Resistances of Various Forms of Target.*

| Year of Experiment. | Name of Ship or Number of Special Target. | Description of the Target. Armour Wrought Iron, unless otherwise stated. | Approximate Weight of the Target per Superficial Foot. | Approximate Number of Superficial Feet fired at. | Total Energy of Projectiles. | Energy of Projectile per Square Foot of Surface of Target. | Maximum Energy of Projectile per Inch of Circumference. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | lbs. | sq. feet. | foot-tons. | foot-tons. | foot-tons. | |
| 1863 | Bellerophon | 6-inch armour, 10 inches teak, frames, skins, horizontal edge stringers, &c. | 393·5 | 171·4 | 17,721 | 100 | 78·92 | No Palliser projectiles used. The plates were twice perforated, but the structure was not. |
| 1865 | Hercules (See diagram) | 9-in. and 8-in. plates, 12 in. teak, two skins of ¾ in. each, frames, between each of which was 10 in. teak, then 18 in. of teak in two thicknesses. A plate of ⅝ iron, and angle-irons. | 9-in. portion 689<br>8-in. portion 652 | 72·6<br>72·6 | 64,499 | 9-in. 378<br>8-in. 513 | 168·5 | No sound part of the target was perforated, but the plates were by chilled projectiles. |
| 1871 | No. 33. Thick portion (sandwich). | 8-in. plate, then 6 in. teak, 5-in. plate, 6 in. teak, 1½ in. skin, frames, &c. | 684 | Not recorded | 25,689 | Not recorded. | 175·3 | Completely perforated by 11-in. projectiles of 533 lbs. weight. |
| 1871 | No. 34. | Bent to represent a turret, 14-in. plate, 15 in. oak, horizontal edge stringers, skin 1½ in., frames, &c. Total thickness 30½ in. | 736 | 102·5 | 53,117 (Direct hits.) | 518 | 182·9 | Much disintegrated. Just a match, but with no margin, for 11-in. and 12-in. 25-ton guns. |
| 1871 | No. 35. (Sandwich.) | Bent to represent a turret, 8-in. plate, 9 in. oak, 6-in. plate, 6 in. oak, horizontal edge stringers, inner skin, frames, &c. Same thickness as No. 34. | 736 | 102·5 | 51,656 (Direct hits.) | 503 | 185·5 | Greater penetration as a rule than 34, but, similarly, no perforation. 11-in. and 12-in. 25-ton guns used. |
| 1872 | Glatton | Turret in place. 14-in. plate backed as No. 34. | 736 | 12′ × 7′2 | 13,500 (Two shot, one not a direct hit.) | 160·7 | 181·0 | No perforation; head of shot got within 2 inches of inner skin. No damage to turning gear or interior of turret. Gun used, 12-in. 25-ton. |

* NOTE.—Taken from a paper by Sir Spencer Robinson, K.C.B., F.R.S.

TABLE showing Comparative Resistances of Various Forms of Target—*continued.*

| Year of Experiment. | Name of Ship or Number of Special Target. | Description of the Target. Armour Wrought Iron, unless otherwise stated. | Approximate Weight of the Target per Superficial Foot. | Approximate Number of Superficial Feet fired at. | Total Energy of Projectiles. | Energy of Projectile per Square Foot of Surface of Target. | Maximum Energy of Projectile per Inch of Circumference. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | lbs. | sq. feet. | foot-tons. | foot-tons. | foot-tons. | |
| 1876 | No. 40 | Three plates of 6¼ in. backed by two layers of wood 5 in. each. Skin, &c., as usual. | 963 | 69 | 11,408 | 165 | 290 | Through, setting teak backing on fire. Just equal to gun (38-ton). |
| 1876 | No. 40 | Four plates of 6½-in., three layers of backing, rest as above. | 1,253 | 69 | 13,911 | 185 | 335 | Extreme penetration 20 in. (38-ton gun chambered). |
| 1877 | No. 41 | Four 8-in. plates, three layers of teak (4 in.) between, backed as above. | 1,520 | 160 | 26,380 | — | 526 | Extreme penetration 25 in. (81-ton gun). |
| 1877 | No. 41 | Do. - - - - - - | 1,520 | 160 | 29,607 | — | 590 | Another series. Extreme penetration 27 in. (81-ton gun chambered). |
| 1877 | Spezzia series | Main features, 22 in. of iron in one or more thicknesses, 19 in. wood, horizontal edge stringers, skin, &c. Steel 22-in. plates were also tried. Cast-iron backing was in some cases used, with and without sandwiches of wood. In all cases it was considered that the width of plates was too small. | 1,041 | — | — | — | — | These targets in all cases resisted perforation by 10-in. and 11-in. projectiles, but when sufficient velocity was given to the 2,000 lb. projectile from the 100-ton gun they were either perforated or destroyed. The steel 22-in. plate was shattered to pieces, but resisted perforation. None of the targets had a resisting power equal to No. 41. |

Steel-faced armour experiments.

## Late Experiments against Steel-faced Armour.

| Target. | 9-inch M.L.R. Gun. Charge. | Projectile. | Energy per inch of circumference on striking. | Remarks. Direct impact. |
|---|---|---|---|---|
| 3½-in. steel + 5½ in. iron; size 8 ft. × 6 ft. 9 in. Secured to wood backing. | 50 lbs. P. | Palliser chill | 124·0 | This plate would have been easily perforated if of iron. Results.—Five successive blows were given without perforation, though plate was much cracked, and if it had been supported at the edges it would probably have stood several other blows. |
| *Targets 4 ft. square, unbacked.* | | | | |
| Iron, 14 in. | 75 lbs. P². | Whitworth steel. | 155· | Penetration 10·4, back opened. |
| Compound, 12 in. | | | 157·9 | Do. 5·8, back unopened. |
| Iron, 14 in. | Do. | Palliser chill | 157·1 | Do. 14.85, daylight through. |
| Compound, 12 in. | | Whitworth steel. | 157·5 | Do. 4·15. |
| Iron, 14 in. | Do. | Cammell chill head; steel body; No. 1 form | 158·7 | Do. 17·92, shell not broken up. |
| Compound, 12 in. | | | 157·7 | Do. 8·35, shell broken up. |
| Iron, 14 in. | Do. | Do. No. 2 | 159·4 | Do. 11·9, back opened, size of hole 2¼ in. |
| Compound, 12 in. | | | 157·7 | Do. slight, shell, broke up. |

Mr. Barnaby's conclusions.

The above is taken from a paper by Mr. Barnaby, and he draws the following conclusions as regards flat plates.

1. A 12″ compound plate may be considered equal to a 15′ iron plate for direct impact.
2. For oblique fire there is, in addition, a considerable advantage in favour of the compound plate.
3. That against steel shells carrying a large bursting charge, such as will probably be used before long, steel-faced armour will be a necessity, and that with improvements in manufacture still more favourable results may be expected from the use of steel.

Spezzia experiments.

The following diagrams* represent part of the experiments carried out at Spezzia in 1876, which are very interesting, as representing the most powerful gun and the thickest ship armour in one plate which have yet been tried.

By reference to the diagram, p. 331, the arrangement of the plates will be seen.

Targets.

The targets were of three descriptions:

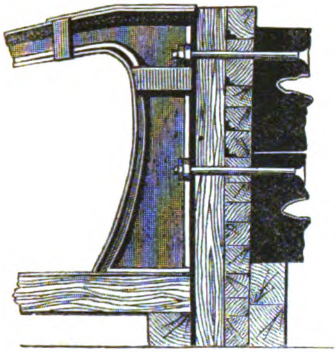
1. Wrought iron by Messrs. Cammell. } These two were put together in one target.
2. „ „ Mons. Marrel. }
3. Steel by Schneider.

Each plate was 22″ thick, 11′ 6″ long, and 4′ 7″ broad. It

* From the war ships of Europe.—*King.*

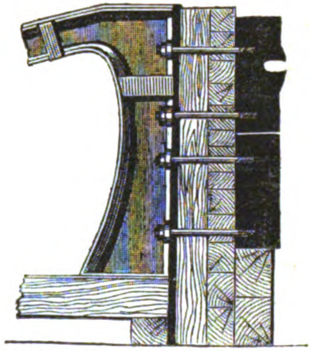
1st Series.

Cammell and Marrel. Iron.




Each struck once by 10" shot.

Schneider Steel.

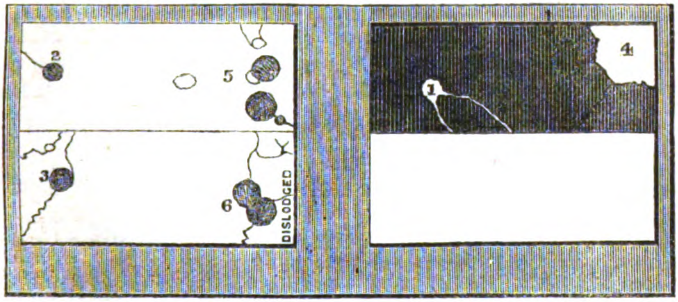



Upper plate struck by one 10" shot.

2nd Series.

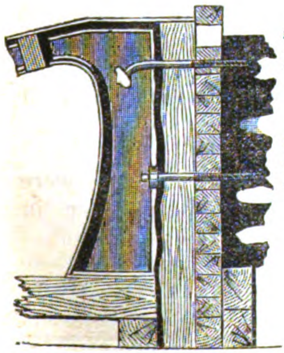
Cammell.

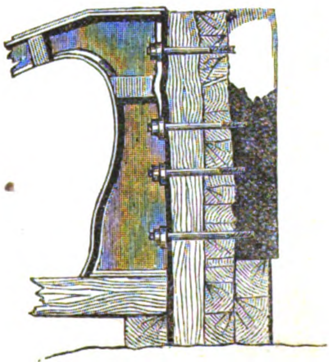
Marrel.




Each target struck by one 10" shot (1st Series) and salvo of one 10" and one 11" shot.

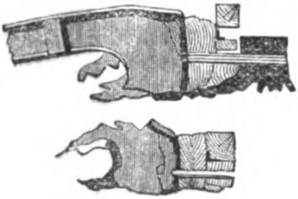
Upper target struck by one 10" shot (1st series) and salvo of one 10" and one 11" shot.



3RD SERIES.

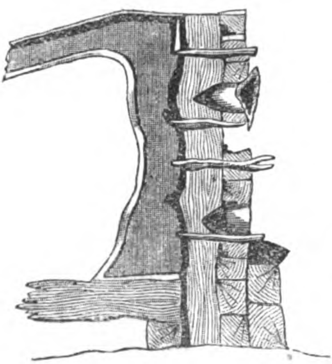
Cammell and Marrel. Iron.



8th fire at Cammell plate from 100-ton gun. Complete penetration; half plate dislodged.

9th fire, 100-ton gun at Marrel plate. Complete penetration; plate in fragments.

Schneider Steel.



10th fire, 100-ton gun at Schneider steel plate already much broken. Now completely destroyed, but backing not perforated.

7th fire, 100-ton gun at untouched Schneider steel plate. Plate smashed to pieces, but target not perforated.

is to be regretted that plates of such a small width were chosen, as the absence of side support probably rendered them much more easily capable of penetration.

The iron plates were bolted on in the usual manner, but the steel plate was secured by bolts screwed in from behind to about half the thickness of the plate.

The wood backing was in each case 29″ and the skin 1½″, the framing representing the side of "Duilio."

Guns.

The guns used were 10-inch, 11-inch, and the 100-ton.

First series.

*First Series.*

10 and 11-in. guns.

The first series of rounds consisted of one shot from the 10-inch M.L. gun against the upper steel, and the Cammell and Marrel plates.

The striking velocity was about 1,525 f.s., giving an energy of about 200 foot tons per inch of circumference of projectile, and the result is shown in the upper diagrams.

No. 1. The shot fired against the steel plate penetrated about 10½″, the plate at the edge of the hole being burred up about 4½″. The plate at first seemed little damaged, but a singing noise was heard in the metal, which soon afterwards split in three cracks, two running to the right edge of the target and the other downwards diagonally.

No. 2. The Cammel iron plate was also cracked, one crack extending from one of the bolt holes to the edge of the target.

No. 3. The Marrel iron plate was also similarly cracked.

Second series.

*Second Series.*

Salvoes.

No. 4. This was against the Schneider plate, and consisted of a salvo from 10-inch and 11-inch guns.

Energy on striking was estimated at about—

200 foot tons per inch of circumference for 10-inch.
217 " " " 11-inch.

Both struck from 2′ to 3′ from right of target. See plan and section in diagram of 2nd series. A large piece of the plate was dislodged from the right-hand top corner, fresh cracks were made, and the original ones opened much wider, in fact the plate was very much injured.

No. 5. Against Cammel plate, salvo, as above.

Plate was struck rather near the edge, and cracks were made from a bolt hole to edge of plate. The whole plate was driven back one inch. Penetration of both shot about 13″.

No. 6. Against Marrel plate, salvo as above.

The 11-inch shot penetrated 15½″, and the 10-inch nearly 15″.

Both struck near the edge of target, and the piece of plate outside was dislodged in fragments.

Third series.

*Third Series.*

100-ton gun.

No. 7. 100-ton gun against untouched Schneider steel plate.

Velocity about 1,470 f. s.; energy per inch of circumference of projectile about 640 foot tons.

The plate was smashed to pieces and the whole target driven back 8″; the inner skin was bulged and opened, and the supports and angle irons torn and twisted, but the projectile was broken up, and had not perforated the backing. It was estimated that the penetration of point of projectile was 21″ into the backing.

No. 8. 100-ton gun against Cammell plate, energy about the same as last round. Half the plate was struck away, all the bolts being broken, and the wood left bare. A hole about 4′ in diameter was made in the target, and part of the projectile passed completely through with considerable remaining velocity.

No. 9. As above, against Marrel plate. The energy was greater than in last round, being about 685 foot tons per inch of circumference.

The plate was knocked into fragments, and almost completely detached from backing; the shot passing through, leaving a large hole in the centre.

No. 10. As above, against upper Schneider steel plate, already much damaged by the fire from the light guns, energy 675 foot tons.

The plate was completely destroyed, and the backing much injured, the head of the projectile remaining in it, but perforation was not obtained.

Land defences.

LAND DEFENCES.

Changed conditions.

Here the consideration of weight, which is all important with regard to ships, has not much effect, and therefore the conditions are changed.

The armour may be made of any desired thickness, and the backing is in many cases composed of iron concrete or granite.

The same remarks with regard to the form and material of the armour plates for ships hold good for land defence armour, with the exception that cast iron of great thickness has been used very successfully without backing.

A short description is given below of this armour, and a record of experiments carried out in England against two forms of protecting shields for embrasures known as the Millwall and Gibraltar shields.

**Gruson's armour.**

Mr. Gruson, the well known manufacturer, has invented an armour-plate of cast-iron.

The brands of iron used are carefully selected, and the plate is so cast that the exterior is chilled, while the interior retains its tensile strength.

**Chilled.**

Mr. Gruson has supplied these plates to Belgium and Italy, and they are in use in the seaforts at the mouth of the Weser, besides some other land defences. Their great weight prevents their use on board ship.

**Experiments.**

The following experiments were carried out in Prussia :—

A turret shield, with maximum thickness of $21\frac{5}{8}''$ and a surface of 99 square feet, withstood 277 6-in., 20 7-in., and 2 11-in. projectiles, and another similar shield resisted 550 6-in. and 7-in. shot.

Throughout the whole of the practice no perforation was effected, and even when the plates were split into two parts, many shots were fired without producing any visible effect.

No injury beyond a crack appeared in the inner surface.

**Advantages.**

The advantages of this system of armour are :—

1. It requires no backing.
2. There are no bolts or fastenings, the plates being connected together by melted zinc being run into a groove in the edges.
3. The expense of rolling and bending plates is avoided, and they can be cast in any shape, such as the dome of a covered turret.
4. The plate can be tapered ; this is done in the dome-shaped plates.
5. With oblique fire the extreme hardness of the plate deflects the shot.

## EXPERIMENTS AGAINST SHIELDS FOR LAND DEFENCE.*

| Year of Experiment. | Name of Special Target. | Description of Target, Wrought-iron Plates. | Approximate Weight of the Target per Superficial Foot. | Approximate Number of Superficial Feet fired at. | Total Energy of Projectiles. | Energy of Projectile per Square Foot of Surface of Target. | Maximum Energy of Projectile per Inch of Circumference. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | lbs. | sq. feet. | | | | |
| 1868 | Millwall shield with a porthole. | Target in two parts, one 9-inch plate, one 6-inch plate above it, a port hole cut out of the middle of each plate. The 6-inch plate was covered for a considerable portion of its length by three 1-inch plates. The whole backed by two sets of 7-inch hollow stringers, one set vertical the other horizontal, filled in with teak, two 1½-inch skin plates in front of the hollow stringers, and a covering plate of 1¼-inch behind all. | The 6 in. 558 | 24·3 | 18,476 | 760 | 152·3 | Uninjured by 14 rounds from guns below 12-inch; after this the 6-inch and 9-inch plates received two shots from 12-inch gun, weight of projectile 600 lbs., without perforation. Guns used, 9-inch, 10-inch, and 12-inch 25-ton. |
| | | | 9 in. 678 | 48·6 | 35,960 | 740 | 153·9 | |
| | | | | 6 in. + 3 in. 24·3 | 11,598 | 477 | | |
| | | | | Total 97 | 66,035 | 679 | | |
| 1867 | Gibraltar shield. | Front plates 5½ inch thick, supported by other plates of 5-inch, then 1½-inch plate; no wood. Total thickness of iron 12 inches. | 458 | 98·2 | 27,103 | — | 110·3 | 9-inch gun was more than a match for this target in its weakest part, but not in its strongest. |

* From a paper by Sir Spencer Robinson, K.C.B., F.R.S.

# MISCELLANEOUS.

## CHAPTER XVII.

## MACHINE GUNS.

### General Remarks.

By the term "machine gun" is meant that particular description of gun in which the loading and firing is carried out by mechanical means; by which, if sufficient ammunition is supplied to the machine, and enough power is continuously applied to move the mechanism, a continuous fire of greater or less rapidity can be kept up. Although the power hitherto applied has been that due to manual labour, there seems no reason to limit the application of this description of gun by the consideration that it must be worked by man power. On the contrary, if the system is to be applied to guns of any size, the use of steam or other power becomes a necessity. Here it may be well to point out that the turret guns of the "Dreadnought" and "Thunderer," and the barbette guns of the "Temeraire," although worked by machinery, are not machine guns according to the above definition. **Machine gun defined.**

Machine guns may be divided into two broad classes, according to the uses for which they are intended, viz.:— **Classes.**

1. Those intended for use against men.
2. " " " material.

The first is simply a development of the small arm, and the various types may well be grouped together under the name of mitrailleur.

The second is the machine gun proper.

In comparing the different guns of either class, the following points must be considered:— **Points to be considered.**

1. Simplicity of mechanism.
2. Non-liability to jam.
3. Portability and facility of handling.
4. Rapidity of fire.
5. Ammunition.

1 and 2. With reference to these points little need be said, as it is manifestly of the first importance that the mechanism **Mechanism.**

should be such that it can be taken to pieces and put together by any petty officer, and that the gun should not be liable to be thrown out of action at the critical moment.

Pertability.

3. For naval purposes, the question of portability may be stated briefly thus :—If the guns are fixtures they must be distributed round the ship, so that under the most favourable circumstances not more than half can ever be brought to bear at once on the same object. The fixed gun should therefore fire considerably faster than the portable one. But even supposing this increased rapidity of fire to be achieved, it will be extremely difficult to arrange a small number of fixed guns so as to effectually cover every point. Making every allowance for the increased facility in working a light and compact weapon, and looking to the weights which a man can carry when the ship is knocking about, and to the positions in which the guns may be placed, viz., tops, bulwark, or boat, the point to decide is, Which system, fixed or portable, will enable a given number of men to maintain the heaviest fire on any threatened point or points? Flatness of trajectory and penetrating power must be also considered, and may so modify the conclusions that portability, perhaps of the first importance for mitrailleurs, may be of only secondary consequence for large machine guns. The question can only be answered after studying the capabilities of various guns.

Rapidity of fire.

4. Rapidity of fire depends upon the system, and to some extent upon the weight.

For naval purposes it is necessary to distinguish clearly between the *rapidity of fire* from the gun considered simply as a machine for pouring forth numbers of bullets, and the *rapidity of hitting* under various conditions. For military purposes the two are possibly nearly identical, but for naval warfare, where the gun and object are usually in motion, the two may be very different, since the latter takes into account the time occupied in aiming, which is omitted in the former.

5. The question of ammunition will be discussed hereafter, as it is different for the two classes of guns.

## 1. Mitrailleurs.

### *Use.*

Importance in naval war.

Any arm by means of which two or three men can pour in a shower of bullets at the rate of not less than 400 rounds a minute, cannot but take an important part in any future naval war. In the face of a few of these guns in close action it would seem to be impossible for any person to remain unhurt in an exposed position on the upper deck, so that

against ships with only an upper deck armament, they will probably be used with most effect. Against boarders the mitrailleur would be most formidable, one gun, well placed, being probably sufficient to sweep away the enemy as fast as they showed above the netting.

**Against coast defences.** In the attack of open batteries the fire from the mitrailleurs in the tops of large ships would be very effective in sweeping away the crews of the guns, provided that the depth of water was sufficient to enable the ships to come to close action. Indeed at the comparatively long ranges of 1,500 and 2,000 yards, a shower of bullets into an open battery may cause considerable inconvenience to the enemy, and would be of great use in shaking his morale if the configuration of the land, shoals, &c. prevents the great guns being brought to bear while moving into position.

**Against torpedo boats.** Against torpedo boats themselves these small machine guns are not sufficiently powerful to do any material damage, but against their crews they could probably be used with considerable effect.

**Boats' armament.** When mounted in boats their use is more doubtful, and in any sea it would seem certain that they are of no use, the motion causing the shooting to be wild in the extreme. For river work, where there would probably be not much motion, they might be used with fair effect, the great volume of fire represented by 400 to 1,000 rounds a minute compensating for the errors introduced by the motion, but even then they would be of little use for searching out cover.

**Summary.** The naval uses may be summed up thus:—

1. To sweep the upper decks of the enemies' ships, and to fire through ports, openings in conning towers, &c.
2. To repel boarders.
3. To pick off the crews of guns mounted in open land batteries.
4. Against the crews of torpedo boats.
5. For boats armaments.

**Ammunition.** The ammunition for these guns is an important point, and it will be readily allowed that the advantage of using the service small arm ammunition is very great, principally on account of simplicity of supply. There are, however, several disadvantages attached to the use in mitrailleurs of the present rolled Boxer cartridge.

1. It is very weak and the base is liable to be torn off by powerful extractors.
2. Owing to the want of smoothness of the exterior and its liability to bend, the possibility of jams is very considerable.

Ammunition.

Should solid cases be introduced for the Martini-Henry rifle, these objections would be removed, and there would only remain the drawback that the guns would shoot no better than the small arm of the same calibre, of which the powder charge and length of barrel are limited to what a man can stand. In other words, the M. V. is maintained at 1,350 f. s., instead of 1,700 f. s., or possibly more.

While very advantageous to be able to use the small arm ammunition, it is no less desirable to increase the shooting powers of the gun. For the naval service, the question of supplying ammunition must be balanced against the great advantages attached to a more powerfully shooting gun.

Mitrailleurs.

The number of mitrailleurs now before the world is considerable, but they may all be divided into two broad classes :—

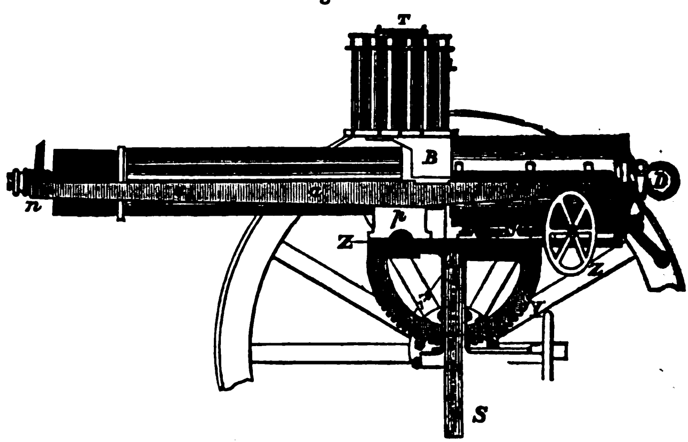
1. Those with revolving barrels, of which the Gatling may be taken as the type.

2. Those with fixed barrels, such as Nordenfelt (or Palmkrantz) and Gardner.

·45 Gatling.

*The ·45-in. Service Gatling.*

**Fig. 1.**



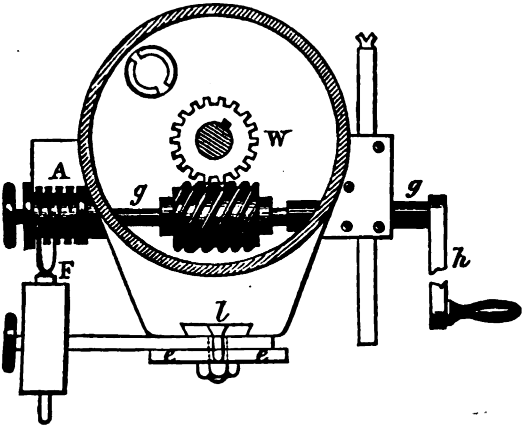

Barrels and Mechanism.

This gun consists of ten steel barrels, rifled on the Henry principle, fixed in a circle round a centre shaft, which is fixed in a "gun-frame" (*aa*, Fig. 1) of wrought iron, made of two bars connected in front of muzzles by a curved cross-piece (*n*, Fig. 1). The rear ends of this gun-frame are connected by screws to a cast-iron box, or "breech-casing" (C, Fig. 1), which contains the mechanism, and is closed by a "cascable-plate" (D, Fig. 1) of cast iron.

Inside the casing, upon the rear end of the shaft, is a small (pinion) worm-wheel (W, Fig. 2), which gears into a worm (*f*, Fig. 2) on a crank-shaft or spindle (*gg*, Fig. 2), which passes into the breech-casing on the right side, and at right angles to the main shaft. By turning a crank-handle secured to this spindle, the main shaft and barrels are caused to revolve. **Barrels and mechanism.**

Fig. 2.

ELEVATION OF BREECH END WITH CASCABLE PLATE REMOVED.




Fastened by screws to the gun-frame, is a "pivot block" of gun-metal (*p*, Fig. 1); a pivot passes through this, and into an iron trunnion-plate (*ee*, Fig. 2).

When a scattering fire is required, the frame, barrels, &c., turn on this "block" through the required arc by means of an automatic arrangement (AF, Fig. 2) worked by the crank-handle before mentioned. When such is not required, the fire is concentrated by putting this arrangement out of gear, and preventing any transverse movement by means of a "locking-bolt" (*l*, Fig. 2) let down into a slot in trunnion-plate at the rear. **Scattering fire.**

On the main shaft in rear of the barrels a cast-iron cylinder, or "cartridge-receiver" (M, Fig. 3) is fixed. This has ten longitudinal grooves, corresponding with the ten barrels. A gun-metal cover, or "hopper" (B, Fig. 1), hinged at one side drops over it.

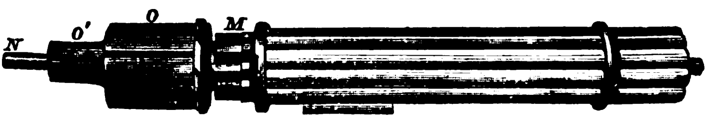



Fig. 3.

The cover has a longitudinal slot, through which the cartridges drop (as the shaft revolves) into the several grooves ready to be pushed by the lock plungers into the barrels corresponding.

**Locks.** In rear of this and inside the breech-casing, is placed the "lock-cylinder" (*o*, Fig. 3), which is keyed to, and revolves with the main shaft. It is a cylinder of cast-iron, having longitudinal channels through which the "locks" pass.

Upon the main shaft, again, and against the back of the "lock-cylinder," is secured a cast-iron "rear guide nut," which keeps the parts firmly together. The locks rest partly upon the outer circumference of this nut; and in the grooves on which they fit, as well as in the channels in lock-chamber, are small slots, in which run studs on the locks, in order to prevent the latter revolving save with the shaft.

Inside the "casing" is a curved gun-metal plate, or cam, by means of which, as the shaft and lock-chamber revolve, the locks themselves are pushed forward or back. A piece of steel is let into the front of this cam, against which the butt of each lock bears the moment the barrel is fired.

There is also a steel cam, called a cocking ring, which, as the lock-chamber revolves, draws back and then releases a spiral spring acting on the "firing-pin" or needle of each lock.

The lock consists of a steel tube, or "plunger," about 11¼ ins. long, the front end of which, for about 4 ins., is smaller in diameter, and has only a pin-hole running through it.

The remainder is hollow, and slotted out on one side. Its breech end is closed by a steel plug, or "butt," screwed in.

Inside is a steel bolt, or "hammer," having a projection at the side which passes through the slot in the tube, while to the front part of it is attached a firing-pin, or "striker," of steel.

A spiral spring is placed over the hammer, being retained by the "butt."

To the outside of the tube or lock is fixed a steel extractor, having a hook, which seizes the rim of the cartridge and draws it out as the lock is being withdrawn.

**Mounting.** The mounting is shown in Fig. 1. which represents the ordinary arrangement for the naval service. It consists of a framework (*n*, Fig. 1) on which the gun can be trained by means of the wheel (*z*, Fig. 1). This framework is carried by a semi-circular elevating arc *y*, which is moved by wheel shown in Fig. 1. A spindle S is placed at the lower part which takes into a socket in the field carriage, top, or boat.

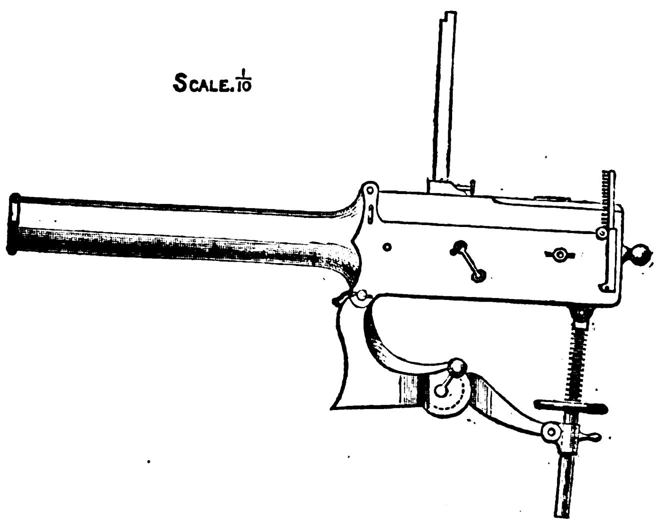
Full directions for the management of the gun will be found in the Gunnery Drill Book and Armourer's Instructions. 45 Gatling.

The above description is that of the gun now in the service, but in later patterns considerable improvements have been made, especially in the feeding arrangement, and system of mounting.

*The Gardner Gun.*

This system has been applied to a gun with either one or two barrels, and possesses several advantages. Its special characteristics are lightness combined with considerable rapidity of fire, and simplicity of mechanism. Fig. 4 shows the general appearance of the two-barrel gun. Gardner.

Fig. 4.




The main features of the mechanism are:—Three brass discs, with ribs cast between, after the manner of a double throw crank, revolve on a steel axis passing through the sides of the body. These ribs cause to-and-fro movement in the plungers, by which the cartridges are pressed home and withdrawn. The movement of the firing pin is also controlled by the movement of the discs. The advantages of this gun are lightness, and simplicity, combined with great rapidity of fire—200 rounds in 30 seconds. Mechanism.

2. Machine Guns Proper.

The great development which has of late years taken place in the speed of torpedo boats, and the well nigh impossibility Machine guns proper.

Machine gun proper.

of hitting a fast moving object with the cumbrous appliances hitherto in use, has necessitated the provision of a weapon which can be laid and loaded with rapidity, and is at the same time powerful enough to inflict serious damage. The guns of this description now before the world are the Gatling ·65 and 1-inch, the Nordenfelt 1 inch, and the Hotchkiss 37 m.m. (1·46 inch).

Looking to the fact that the 8·7 c.m. Krupp gun has been fired without recoil, and that a Hotchkiss' 4-pr. already exists, there would appear some probability that machine guns of increased size will be produced in the near future. Such guns would be most formidable against unarmoured ships.

*The ·65 Service Gatling.*

·65 Gatling.

The mechanism of this gun is essentially the same as the ·45 gun previously described, except that it has no scattering arrangement.

*Nordenfelt Gun.*

Nordenfelt.

A gun of 1-inch calibre on this system is now in use in the navy.

It consists of a rectangular framework of wrought iron, the sides of which are connected by three plates or transoms.

The four barrels are placed side by side in the frame, their muzzle ends passing through the front transom, while the breech ends are screwed into the middle transom.

Action block.

In rear of the middle transom is the action block, which is capable of movement backwards and forwards.

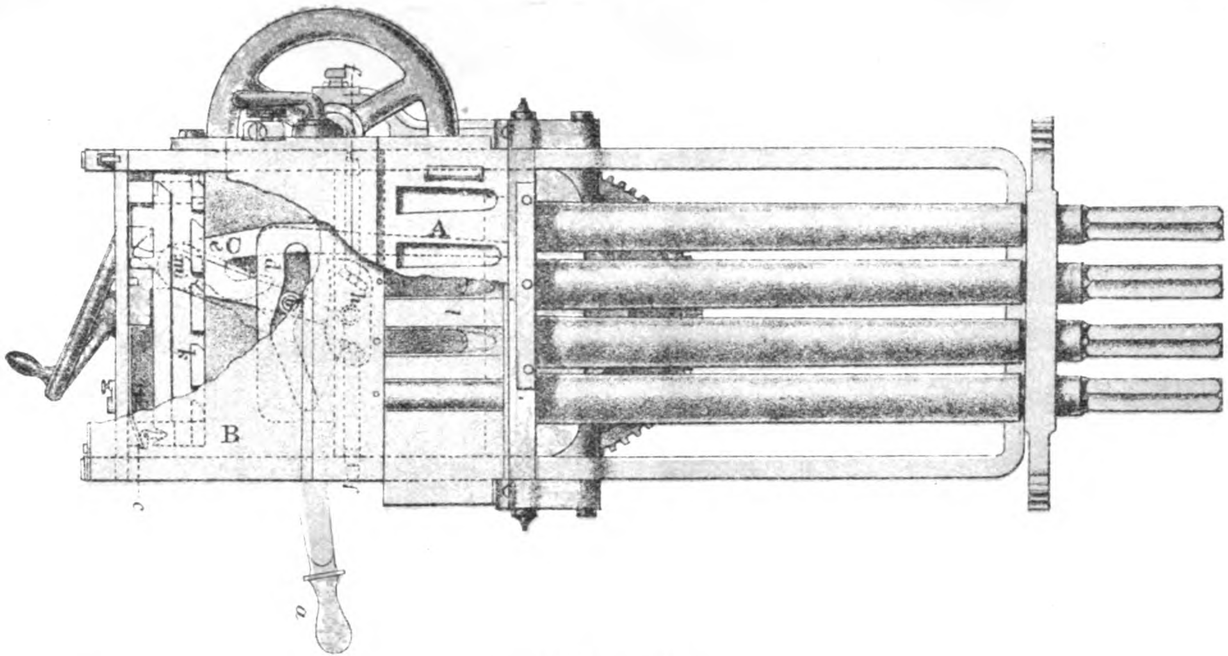
In front of the action block are four breech plugs, (*n* in elevation) corresponding to the barrels. These are of steel, pierced with a channel, in which a firing pin or striker moves freely, and are furnished with an extractor on the right side. Behind each plunger is a hammer, with a projecting tenon; and behind the hammer a strong spiral spring.

On the under surface of the action block is—

1. A locking cam (*h*), which pivots on an axis, and by means of two curved slits gives reciprocating motion to the locking bolts (*ff*).
2. A director or action plate (*d*), which is a cam secured to the action block, and having a slit into which fits a roller working on a stud on the action lever.

   A portion of this slit is the arc of a circle, concentric with that described by the arm; the remainder is straight, so that as the arm moves from the right to left the action block advances, and *vice versâ*.

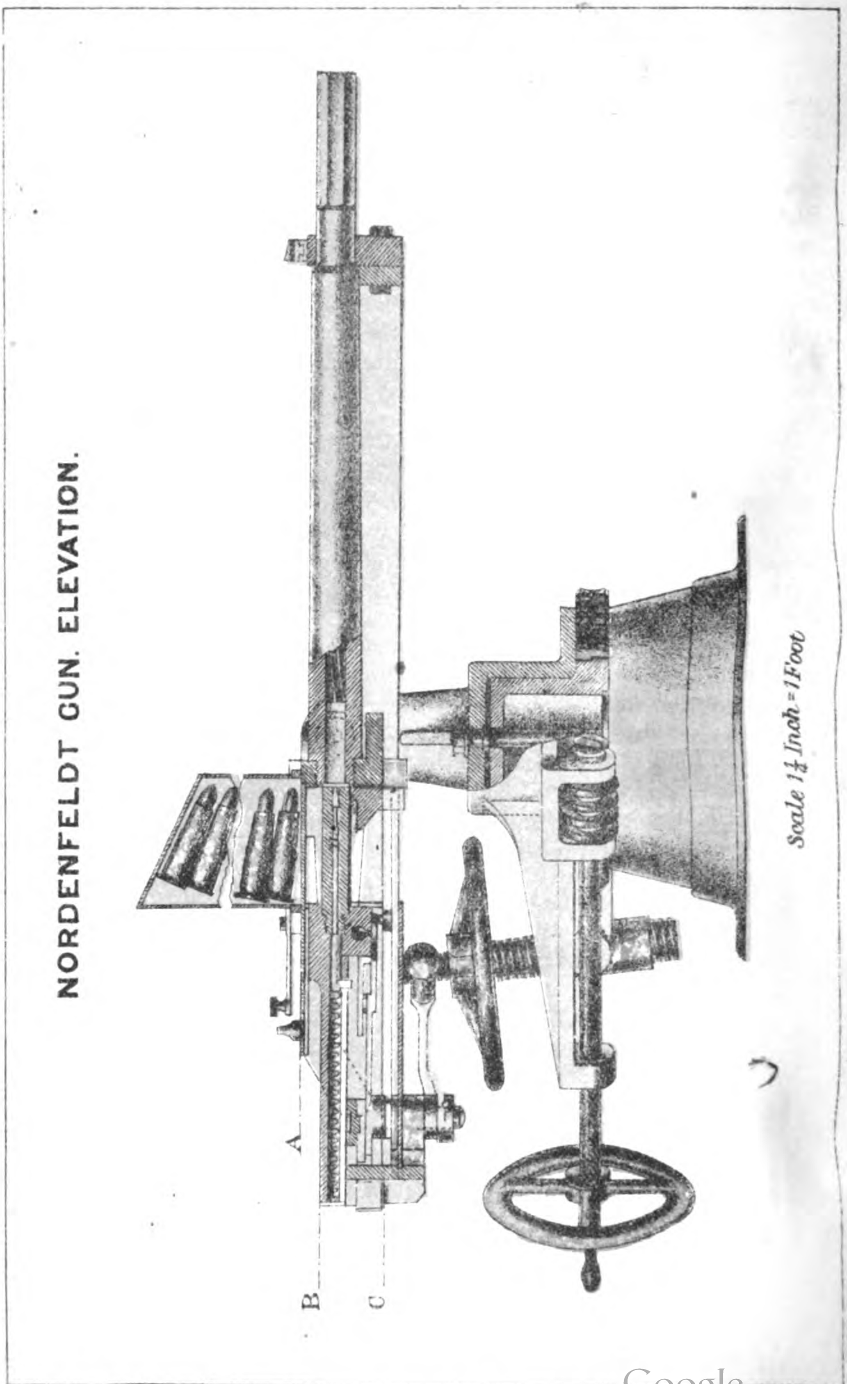
# NORDENFELDT GUN. PLAN.




*Scale $1\frac{1}{4}$ Inch = 1 Foot.*

*To face page 344.*

DANGERFIELD LITH. 22 BEDFORD ST. COVENT GARDEN.




*To face page 345.*

Upon the brackets, secured to the rear transom, is the "trigger comb" (*k*). This is a plate, capable of transverse movement, and having four teeth bevelled on the left side. A powerful spring (*c*) fastened to the rear transom, presses the trigger comb against the left side of the frame. The carrier (*l*) is a cast-iron plate, having four longitudinal holes for the cartridge cases to drop through when extracted, and a similar number of strips on which to carry the cartridges when loading. It is capable of a slight lateral motion which is given by the arm (*e*) pivoting freely on the motive axis (*m*), and moved to the right or left by a projection on the under surface of the action block. The whole mechanism is set in motion by the lever handle (*a*), which is fixed to the motive axis (*m*). **Trigger comb.** **Carrier.**

The mounting of this gun is shown in the annexed diagrams. The trunnions fit into a cross-head pivoting on a cone, which is firmly fixed to the gunwale or other part where it is to be fired. The training is given by a hand wheel, which works a worm wheel gearing into a horizontal toothed rack attached to the top of the cone. The elevation is produced by a wheel working a differential screw. **Mounting.**

The action of the mechanism is as follows, supposing the discharge to have been just completed, the lock closing the breech end of the barrels, and being still secured in its place by the two bolts (*f f*):— **Action.**

1. The handle (*a*) begins to move to the rear; the projection (*b*) of action lever traverses the concentric part of the action plate (*d*), and the action block remains steady. **Handle moving to the rear.**

   The spring (*c*) and the heel of the lever, acting on trigger comb, drives it from right to left.
2. As the movement continues, the arm, by means of the tenon (*b*), acts on the closing cam (*h*), and withdraws the bolts (*f f*), leaving the action block free.
3. At the moment these bolts are withdrawn the projection (*b*) engages in the straight part of action plate, and the action block begins to move back, drawing with it the plungers which extract the cartridge cases.
4. When the plungers are clear, the projection on action block bears against the forked arm (*e*), and so pushes the carrier to the left. At the same time the cocking cam begins to press against the tooth of the trigger comb, carrying the latter to the right.

   The empty cartridge cases fall to the ground and are replaced by filled ones. The tenons of the hammers pass behind the teeth of trigger comb, which is driven to the left by the spring (*c*), or by the cocking cam as the action block moves forward.

The handle ($a$) is now as far back as possible, and the lock in its furthest position from the barrels.

Handle moving forward.

The handle next moves forward with the following effects:—

1. The projection on the action lever acts on the director, and moves the action block to the front. The action block, pressing against the fork ($e$), drives the carrier to the right, thus placing the cartridges in line with the barrels.
2. The ($b$) lock advances to the front, and the spiral springs are compressed by the hammers, which are kept back by the trigger comb which again is held firm by the heel of the action lever. The plungers push the cartridges into the barrels.
3. When the cartridges are quite home the action block stops, and the pin on the directing arm causes the closing cam to drive the bolts ($f\,f$) into the holes in the gun-frame, so that the breech-closing is complete.
4. The action lever now begins to carry the trigger comb, to the right.

   Each hammer is released in turn from the tooth which retains it, and the striker pertaining to it is driven forward in consequence.

*Hotchkiss Revolving Cannon.*

Hotchkiss gun. Parts.

This gun has been largely introduced into the French and other navies, and is for that reason described here.

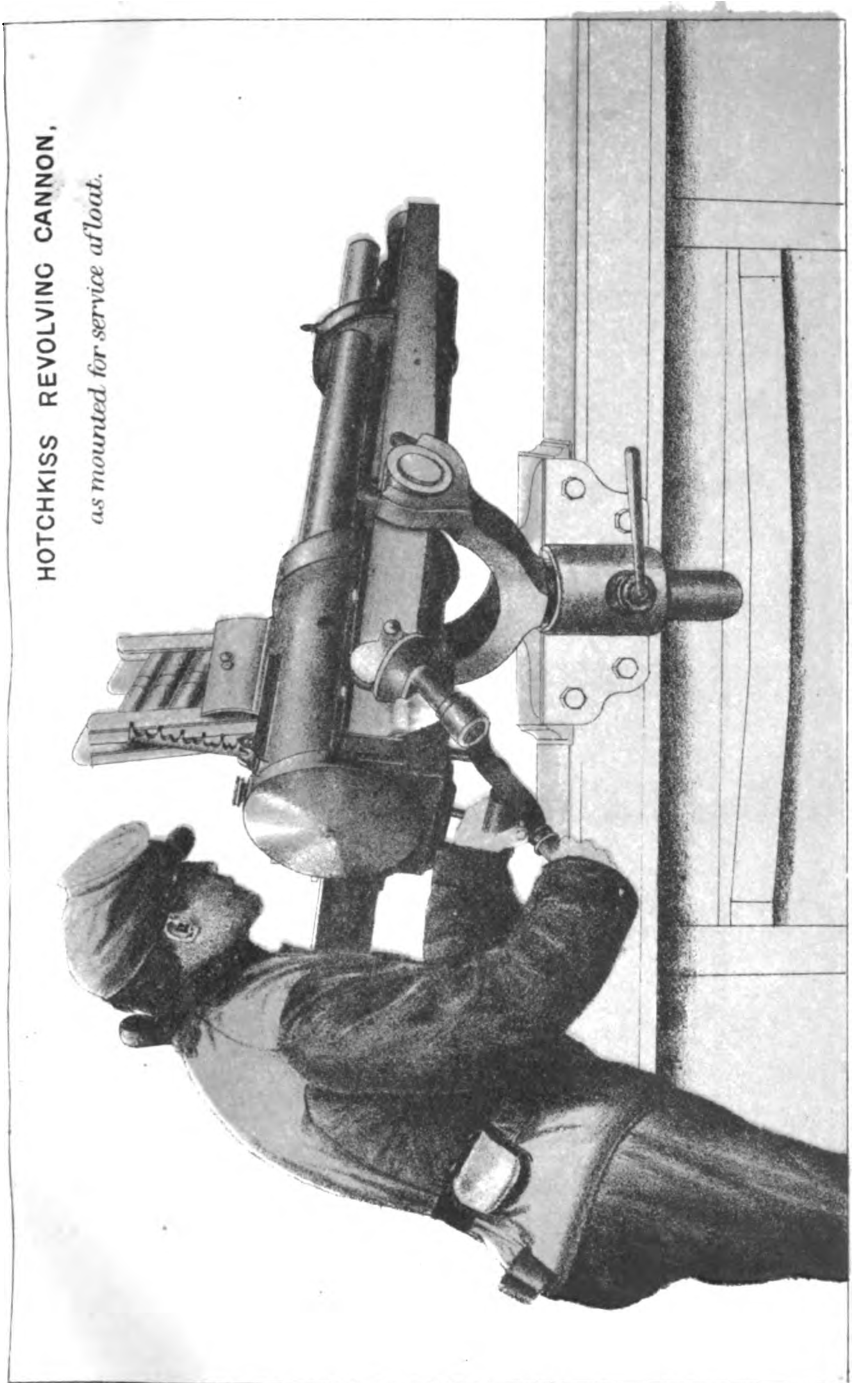
The gun consists of four distinct parts, viz.:—

*a.* The group of barrels.
*b.* The frame, carrying the trunnions, and serving as a bearing for the forward end of the central shaft.
*c.* The breech containing the mechanism.
*d.* The mechanism.

The general features will be understood by reference to the attached diagrams. The breech is comparatively heavy, massive at its face, and absorbs the greater part of the recoil. The mechanism for rotating the barrels, and performing automatically the functions of loading, firing, and extracting is composed of the crank shaft F, carrying a worm H, which works in a pin wheel $b$ on the rotating axis of the barrels.

The worm H is curved so as to impart an intermittent rotating motion to the barrels, while the worm is rotated continually.

The worm H carries at its right side a cam G. The arm $n$ of the firing pin N bears against this cam, and is by the rotation drawn back, and allowed to fly forward at the proper time under the action of the spring $o$, and so strikes the cap.

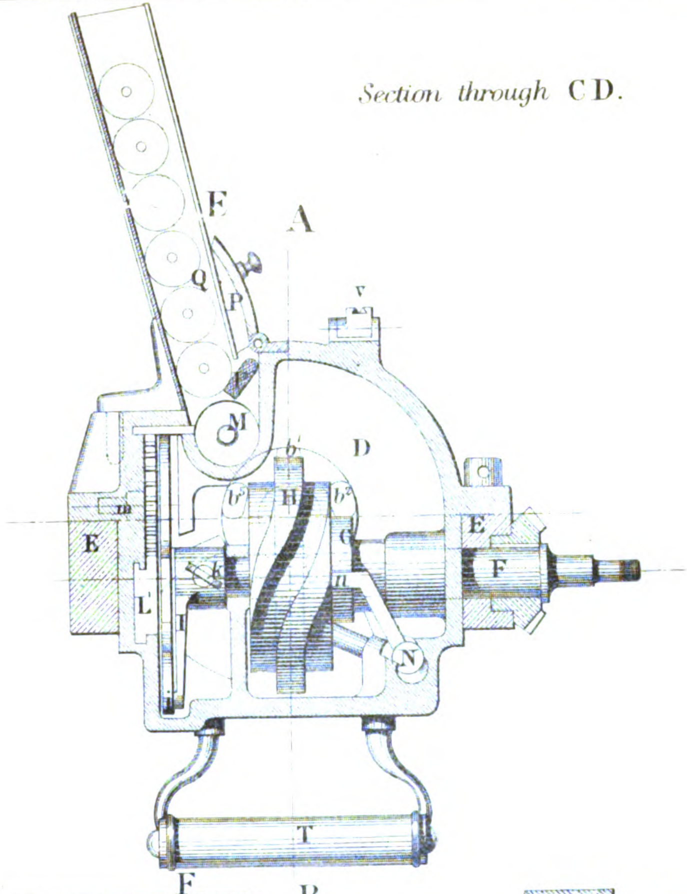


HOTCHKISS REVOLVING CANNON,

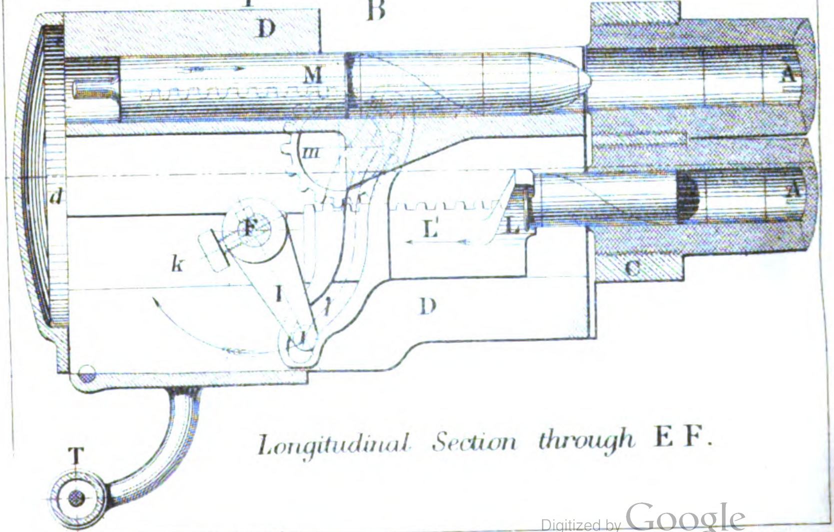
*as mounted for service afloat.*

To face page 346.

Dangerfield Lith 22 Bedford St. Covent Garden




Section through CD.




Longitudinal Section through E F.



To face page 347

Dangerfield. Lith 22. Bedford St Covent Garden.

The loading and extracting is effected as follows:—

On the interior face of the left side of the breech, a cog wheel *m* is mounted, with two horizontal racks $L^1$ and $M^1$, running in slides, so arranged that in moving one of them the other is moved by the cog wheel *m* in the opposite direction. Part of the lower rack forms a curved link or yoke, in which a small crank I on the crank shaft *f* works. The rotation of the latter consequently imparts an alternating and opposite movement to the two racks, so that a fired cartridge case is extracted whilst a loaded cartridge is being introduced into the barrel above. The cartridge is not "driven home" entirely, but it is within reach of a helical ramp R, on which it slides when it is moved by the rotation of the barrels. This completes the introduction of the cartridge into the chamber. **Loading and extracting.**

When the racks $L^1$ and $M^1$ are in the extreme positions they remain stationary a moment whilst the barrels are still revolving. This is necessary to cause the head of the cartridge case to engage in the hooks of the extractor, and to provide time for the new cartridge to enter the introduction trough. The extractor proper L, consists of two grooved lugs at the end of the rack $L^1$, into which the head of the cartridge is engaged by the rotation of the barrels. After the cartridge is withdrawn from the barrel it strikes against an ejector, which pushes it out of the extractor, and it falls to the ground through an opening in the breech.

Each cartridge as it enters the receiver is isolated from the others by a hinged gate P, which is raised by the loading piston as it moves forward. This prevents jamming of the cartridges.

The operation of the mechanism is—

The supply of cartridges is regulated by the feed gate P; the barrels are loaded by means of the loading piston M; the intermittent rotating motion is imparted to the group of barrels by the worm H; the cartridges are fired by the firing pin N, this in turn being operated by the cam G; and, lastly, the fired cartridge cases are withdrawn by means of the extractor L, which is actuated by the crank I, the movement to the whole mechanism being imparted by turning the hand-crank. **Action.**

The peculiar advantages claimed are:— **Advantages.**

1. Intermittent rotation of the barrels, without rotation of the breech or mechanism.
2. The barrels remaining stationary during discharge, the loading and extracting also taking place during this stop.

3. The use of but one single loading piston, one firing pin, and spring for all the barrels.
4. The shock of discharge is received against a massive immoveable breech of considerable weight, which is connected to the trunnions by means of four bolts.

Mounting.

The mounting of this gun is one of its most important features. The trunnions fit into the arms of a universal forked pivot, of which the socket is placed wherever it is desired to fight the gun. This arrangement, combined with the handle and shoulder piece shown in the diagram, enables one man to lay and fire the gun with great facility.

### Weights, Dimensions, &c. of Gatling Guns.

| — | | ·65 in. | ·45 in. Old Pattern. |
|---|---|---|---|
| Weight of gun, including scattering gear | lbs. | 787 | 426 |
| " mounting for ship | " | — | — |
| " drum, empty | " | 28·6 | 26 |
| Total weight | cwt. qrs. lbs. | 7 " 1 " 5 | 4 " 1 " 18 |
| Barrels, number | | 10 | 10 |
| " calibre | inches | ·65 | ·45 |
| " length, extreme | " | 33·0 | 31·9 |
| " " from base of bullet to muzzle | cal. | 46 | 66 |
| Rifling, description | | Henry. | Henry. |
| " number of grooves | | 7 | 7 |
| " twist, uniform | in calibres | 1 in 46 | 1 in 48·8 |
| " length of | inches | 28·1 | 29 |
| Hopper, number of columns | | 10 | 16 |
| " number of cartridges in each column | | 5 | 15 |
| " weight, filled | lbs. | 46·3 | 50·3 |

### *Ammunition.*

| — | | ·65 in. | ·45 in. |
|---|---|---|---|
| Projectile, nature | | Lead | Lead. |
| " weight | oz. | 3¼ | 1·1 |
| " length | cal. | 3 | 3 |
| Charge, powder, nature | | R.F.G.[2] | R.F.G.[2] |
| " weight | oz. | ·6 | ·19 |
| Cartridge case, weight of | " | ? | ? |
| Total weight of cartridge | " | 5·5 | 1·8 |
| No. of men to work 100 rounds | | 4 | 3 |
| Time occupied in firing 100 rounds | sec. | 43 | 24 |
| No. of men to work 50 rounds | | 3 | 3 |
| Time occupied to fire 50 rounds | sec. | 15 | 11 |
| Muzzle velocity | f. s. | 1427 | 1360 |
| Velocity at 500 yards | " | 973 | 883 |

## WEIGHTS, DIMENSIONS, &c. OF NORDENFELT and HOTCHKISS GUNS.

| — | | Nordenfelt 1 inch. | Hotchkiss 37 m.m. |
|---|---|---|---|
| Weight of gun | lbs. | 426 | 441 |
| „ mounting | „ | 357 | 121 |
| „ hopper, empty | „ | 20 | — |
| Total weight | „ | 803 | 562 |
| Barrels, number | - | 4 | 5 |
| „ calibre | inches | 1 | 1·46 |
| „ length, extreme | „ | 35·46 | 29·18 |
| „ „ from base of bullet to muzzle | cal. | 33 | 17 |
| Rifling, description | - | Henry | — |
| „ number of grooves | - | 11 | 12 |
| „ twist | in calibres | Uniform 1 in 60. | Uniform 1 in 29·9 |
| „ length of | inches | 31·37 | 24·6 |
| Hopper, number of columns | - | 4 | — |
| „ number of cartridges in each column | - | 10 | — |
| „ weight, filled | lbs. | 48 | — |

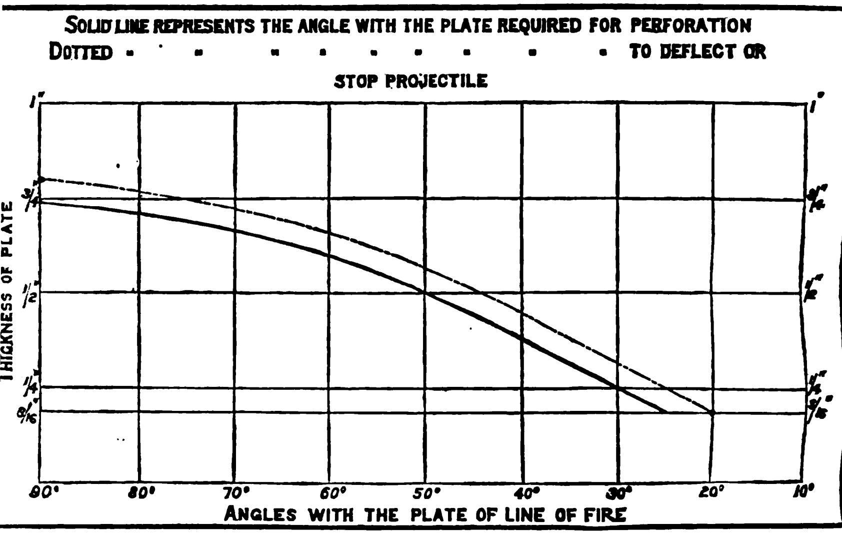
### *Ammunition.*

| — | | Nordenfelt 1 inch. | Hotchkiss 37 m.m. |
|---|---|---|---|
| Projectile, nature | - | Solid steel | Cast iron shell. |
| „ weight | oz. | 7·25 | 16 |
| „ length | cal. | 2·6 | 2·5 |
| „ bursting charge | oz. | — | ·75 |
| Envelope or coating, weight of | „ | ·8 | — |
| Charge, powder, nature | - | Special | French Ripault. |
| „ weight | oz. | 1·43 | 2·9 |
| „ space occupied per lb. | c. in. | 19·0 | 27·7 |
| Cartridge case, weight of | oz. | 2·52 | 3·35 |
| Total weight of cartridge | „ | 11·21 | 22·25 |
| No. of men to work 100 rounds | - | 3 | 2 |
| Time occupied in firing 100 rounds | min. | ½ | 2 |
| No. of men to work 40 rounds | - | 2 | 2 |
| Time occupied to fire 40 rounds | sec. | 7 | 48 |
| Muzzle velocity | f. s. | 1,417 | 1,318 |
| Energy per inch of ⊙ at muzzle | ft. lbs. | 4,498 | 5,880 |
| Total energy at muzzle | „ | 14,132 | 26,973 |

*Effect of Machine Gun Fire.*

*Nordenfelt* 1″ *Gun.*

The following diagram shows the effect produced by this gun against steel plates of various thicknesses at different angles at 200 yards.




At 300 yards the present service ammunition is just capable of perforating $\frac{5}{8}$″ steel.

Experiments have shown that torpedo boats as now constructed would be perforated, whether end on or broadside on, at all ranges up to 1,500 yards, also that in positions other than end on the boiler would be damaged at distances up to about 500 yards.

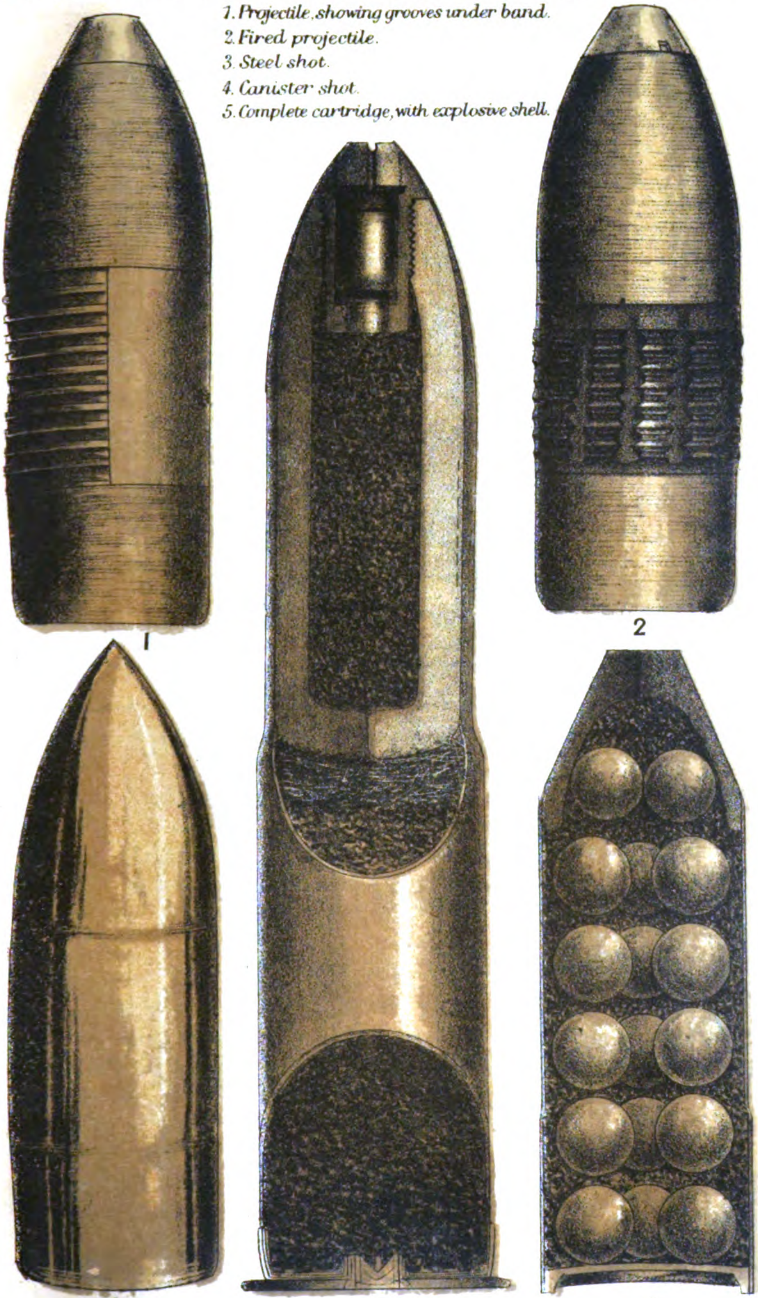
*Hotchkiss* 37 *m.m. Gun.*

The French experiments with this gun show that the shell filled and fitted with a percussion fuze will perforate $\frac{3}{16}$″ steel plates up to 2,000 yards, and $\frac{6}{10}$″ steel plates up to 400 yards, when fired at direct. This gun would, therefore, be effective against torpedo boats, but would not pass through the sides of unarmoured ships.

m.m. gun. The 53 m.m. gun could, however, be used with effect against the light upper works of some ships, and against merchant steamers.

## AMMUNITION FOR HOTCHKISS REVOLVING CANNON.

1. *Projectile, showing grooves under band.*
2. *Fired projectile.*
3. *Steel shot.*
4. *Canister shot.*
5. *Complete cartridge, with explosive shell.*

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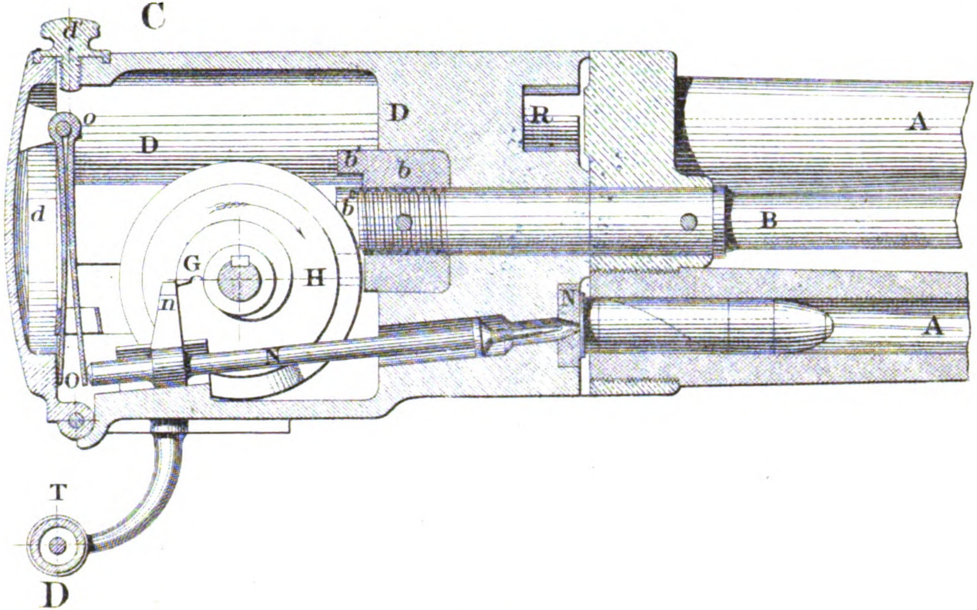
DANGERFIELD LITH 22, BEDFORD ST. COVENT GARDEN.

Longitudinal Section through AB.

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# CHAPTER XVIII.

## AMMUNITION.

### CHARGES.

*General Remarks.*

See Drill Book, p. 71, and Treatise on Ammunition, p. 121 et seq.

For safety, rapidity, and convenience of loading, the charge of powder which is placed in a piece of ordnance is enclosed in an envelope called a cartridge. **Cartridges, requirements.**

A good cartridge for service should possess the following qualifications:—

1. The material should be strong enough to bear reasonable knocking about when filled.
2. It should be so close in texture as not readily to admit of the powder, if slightly dusty, working its way through, and yet be permeable to the flash from the tube, &c., intended to fire it, even if not well "pricked."
3. Lastly, and this is of the greatest importance, the material should consume entirely in the gun when fired; or, if this end cannot be obtained, it should leave no smouldering fragments, or sparks, in the bore.

These conditions are very well fulfilled by the materials in use in the service, *i.e.*, serge and silk cloth. All cartridges in our service are made of these materials, with the sole exception of the 4-oz. charge for the 7-pr. gun, which is contained in a red shalloon bag. **Materials.**

Experience having shown that serge is hardly strong enough for the heavy charges now used, silk cloth, which is stronger and of closer texture than the serge, and is not so liable to smoulder in the bore, has been introduced, and will be used in future for all cartridges for R.M.L. guns. The present stock of serge cartridges will, however, be exhausted.

All serge cartridges are hooped with blue worsted braid; **Hooping, &c.**

Hooping.

while silk cloth cartridges are choked and hooped with silk, the hoops being braid for some, silk twist for others.

Cartridges are marked with ink. Paint should never be used as it renders the cartridge liable to hold fire.

The diameter of the cartridge is made smaller than the diameter of the bore to ensure easy loading and to give air space.

### *M.L.R. Cartridges.*

Cartridges for M.L.R. guns.

See Treatise on Ammunition, p. 214 et seq.

All cartridges containing 22 lbs. of powder and upwards (except the charge of 22 lbs. P. for 7-inch gun) have a becket over the choke to enable them to be easily withdrawn from the cases. The becket is of the same material as the cartridge.

For hydraulic loading.

When guns are loaded by hydraulic machinery there is a probability of the cartridge, if rammed home very hard, being set up into a smaller portion of the length of the bore than it ought to occupy, and accordingly a stick has been approved for the cartridges of such guns, to be put in the axis of the cartridge, and so keep it the proper length.

For convenience of loading it is also intended to make the 160 lb. charge for the 12·5 inch gun and the 140 lb. charge for the 12-inch 35-ton gun in two parts.

For 64 pr.

Serge cartridges are not to be used for 64-prs., marks I., II., and III. This is in consequence of the vent being considerably forward in all these guns and of the small amount of heat developed, which necessitates the employment of all available means to guard against smouldering fragments of the cartridge being left in the bore.

### *B.L.R. Cartridges.*

See Treatise on Ammunition, p. 166 et seq.

For B.L.R. guns.

A lubricator, consisting of two thin cups of tinned iron soldered together, containing a mixture of equal parts of tallow and linseed-oil, attached to a felt wad, is inserted into the cartridge just above the top hoop, except in the case of 40-pr. cartridges, which have their lubricators detached to save room in the magazine.

The use of the lubricator is to prevent the guns from leading, the cups being crushed by the discharge, the lubricant is squeezed out, and the wad following wipes and polishes the bore.

When 20-pr. guns are used for saluting these lubricators must be removed.

With the 40-pr. and 20-pr. cartridges a paper cylinder is used to bring them up to length. **For B.L.R. guns.**

## M.L.R. Projectiles.

### *General Remarks.*

See Treatise on Ammunition, p. 175 et seq.

The projectiles fired from the service guns are all fitted with some means by which rotation can be given to them. Case shot, except that for the 12″·5 gun, are excepted. **Projectiles fo M.L.R. guns. Rotation.**

In the Woolwich system the rotation is usually given by two rings of studs made of an alloy of copper and tin; they are secured to the shells by being pressed into undercut holes.

The later patterns of projectiles for the 35 and 38-ton guns have three rows of studs.

Guns of 8″ and above, being rifled with an increasing twist, have the front studs smaller than the rear; in lower natures they are of the same size.

The projectiles for 64-pr. guns have three rings of copper studs of small size, so as to fit both the shunt guns and those with plain grooves.

The projectiles for the 9 and 7-pr. guns have two rings of copper studs.

The various projectiles for each calibre of gun are generally brought to the same weight (except case shot and double shell). It has not, however, been found practicable to do this in all cases. The 12-inch 25-ton gun has an exceptionally slow twist, therefore a long projectile cannot be fired from it, hence the weights of the common and Shrapnel shell are much less than those of the Palliser projectile. **Weight and length.**

The 12-inch 35-ton gun has a twist as rapid as the majority of Woolwich guns, but even with this twist it would be impossible to lengthen the common shell or Shrapnel, so as to bring them up to the weight of the Palliser projectiles, which are exceptionally heavy for a gun of that calibre. By reference to the table, p. 368, it will be seen that the common shell is nearly three calibres in length, beyond which with this gun it is impossible to go without injuring the shooting qualities of the shell.

With reference to this point it may be observed that to ensure steadiness of flight the twist of rifling for a particular gun must be determined for the longest projectile,

while such a sharp twist is not required for the shorter ones. To obviate this some gunmakers use projectiles of constant length, and therefore of different weight. This plan involves complication in the sighting and range tables.

Marking.

The projectiles for each gun may be recognised by the calibre being cast on the base, the weight of gun is also given for the 12-inch projectiles. Shell cast prior to 1873 are not thus marked, but they may be known by the number of studs in each ring, except in the 11-inch, 12-inch, and 12·5 inch, which have the same number of studs. The number of grooves in each gun will be seen in the table, p. (272).

### *Gas-checks.*

Gas-check.

See Treatise on Ammunition, p. 134 et seq., and Appendix, p. 13.

Scoring.

Reports of Committees.

Soon after the introduction of the Woolwich guns it became apparent that the rush of gas past the projectile, and especially over it, caused a most serious erosive action, called scoring. Attempts were made to obviate this by means of various descriptions of wads, but were soon abandoned, and a committee, specially appointed to consider the subject, reported that, "in their opinion, the scoring action of the powder " gases in heavy M.L. guns of the present service pattern was " not likely to be obviated by the employment of any nature " of wad, but that the desired result might be arrived at by " the introduction of some suitable form of gas-check."

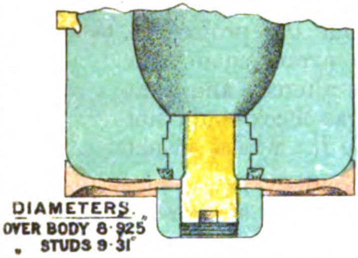
Experiments were carried out, and on the 21st October 1874, the Committee reported, "that a gas-check could be pro- " duced which would adhere to the projectile throughout its " flight, and the use of which ensured a gain in length of " range and accuracy of shooting. They further state, " that the erosion in the bore of the gun would be mitigated, " as the windage appeared to be nearly, if not altogether, " closed by the gas-check."

In June 1875, the Committee on Explosives reported that the use of Lyon gas-checks in a 12″·5 gun caused no material increase of pressure in the gun, and that a considerable gain in muzzle velocity was obtained.

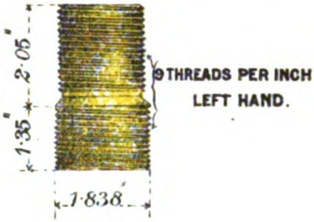
Increased power of guns.

The following experiments carried out with the 12″·5 gun in 1877 show the increased power obtained by using gas-checks. With a 130 lb. charge and studded projectile the mean range of 5 rounds fired with 5° elevation was 3003 yards, while with the Butler automatic gas-check and a charge of 110 lbs. only, the mean range under the same conditions was 3198.

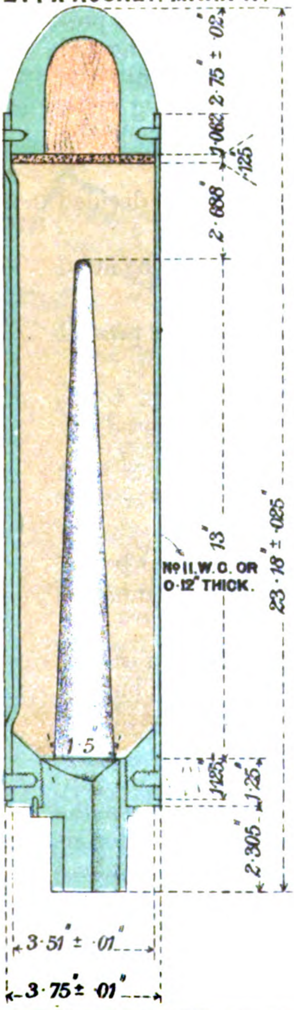
PALLISER 9" SHELL. MARK IV.



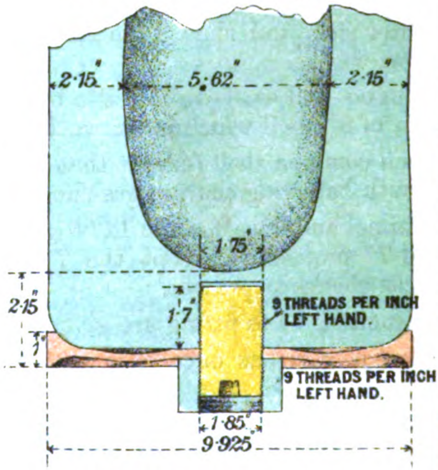

METAL PLUG FOR GASCHECKS MARK I.



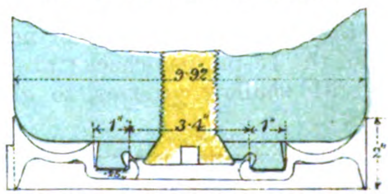

24 PR ROCKET. MARK IV.




10" COMMON SHELL. MARK II.




GOOLD ADAMS GAS CHECK

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DANGERFIELD LITH. 22 BEDFORD ST. COVENT GARDEN.

The navy, however, desired an automatic gas-check which could be carried and loaded separate from the projectiles. The reasons for this were that all the arrangements for stowage of projectiles would have to be altered, and that under the conditions of naval service the gas-check could not be kept on the projectile without injury to it; whilst if not automatic, time would be lost in fixing it. **Naval requirements.**

Many experiments have been carried out, and at present two modifications of the Lyon gas-check have been adopted for use with the 9″ and higher natures of guns. **Lyon gas-check adopted.**

They differ merely in the method of attachment to the projectile, in the one case a solid gun metal plug with hexagonal head after passing through the gas-check is screwed into the base of the shell, and in the other, a projecting plug with enlarged head is kept permanently fixed in the shell, the gas-check fits over this and a nut is screwed on.

Up to August 1878, the following particulars were decided on:— **Orders to Aug. 1878.**

Palliser shot and shell 9″ to 12″·5 inclusive* will be fitted with gas-checks.

Common shell as above will also be fitted, except the present pattern of 9″ shell which is too weak.

When common shell (except that for 12″·5 gun) are to be fired with battering charges gas-checks are not to be used.

Shrapnel and case for the 12″·5 gun only have gas-checks. 8″ and 7″ projectiles, except the 7″ double shell, are not to have gas-checks at present.

Instructions as to fitting are given in Drill Book, p. 74.

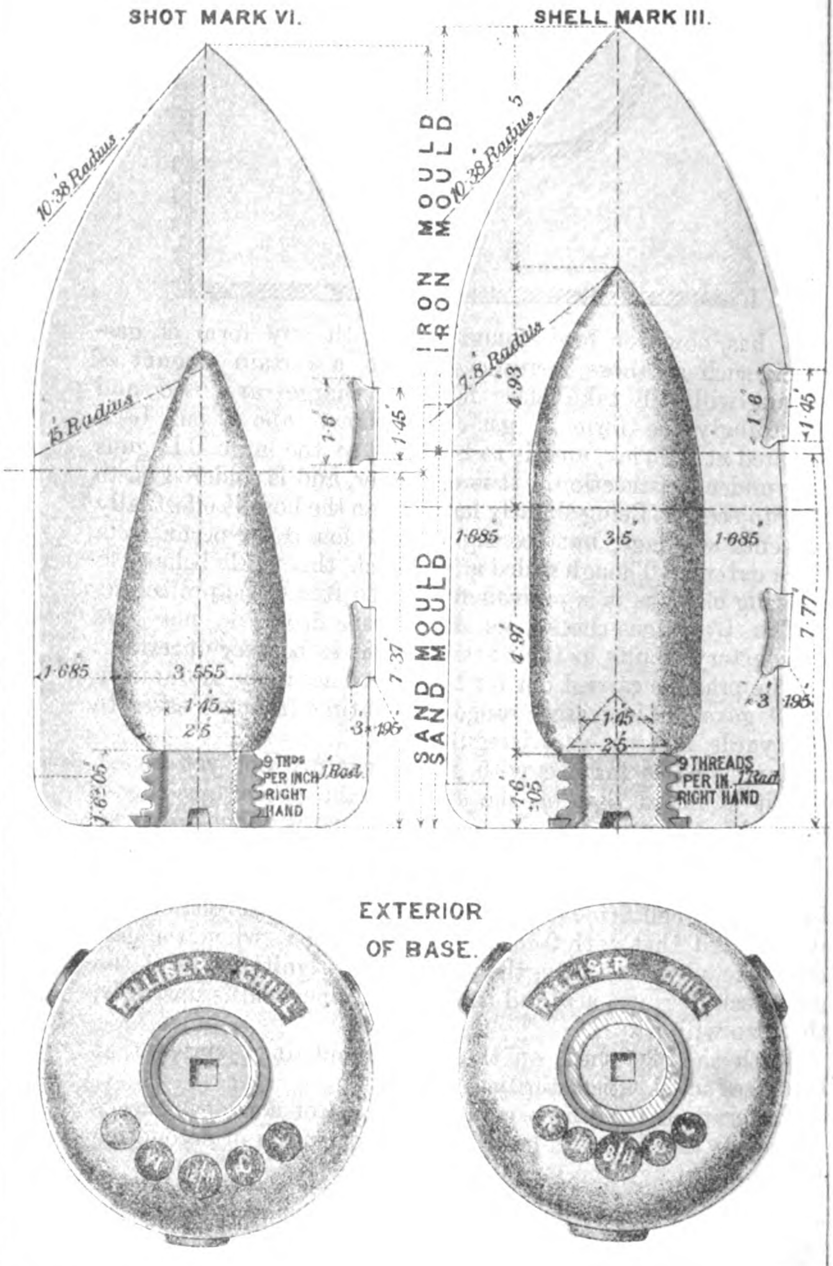
When a gun has once been scored, gas-checks cannot be used.

Since the above date further experiments have been carried out, and the whole subject is still under consideration, but the Goold-Adams gas-check (*see* Plate) will probably supersede the Lyon gas-checks referred to above.

These gas-checks are only employed as a means of suppressing the windage, but in the newer guns, such as the 80-ton and the 13-pr., gas-checks are to be employed in conjunction with shallow grooves, to give rotation to studless projectiles.

* Except 9″ Marks I. and II., 10″ Mark I., and 12″ Mark I.

# 7 INCH PALLISER.

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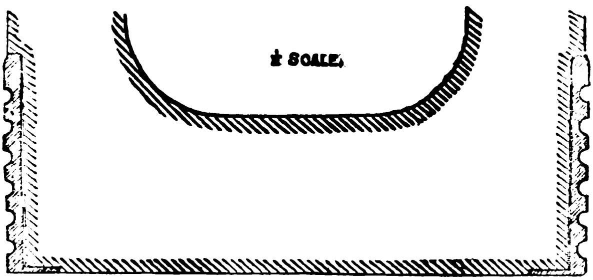
DANGERFIELD LITH. 22 BEDFORD ST. COVENT GARDEN.

FIG. 3. ELSWICK GAS-CHECK FOR B.L.

Elswick for B.L. guns.



It has, however, been found that with any form of gas-check, such as those mentioned above, a certain amount of scoring will still take place if heavy charges are used, and accordingly the form of gas-check shown above has been adopted at Elswick, and is to be fitted to the large B.L. guns now under construction. It is of copper, and is soldered on to the projectile. Being slightly larger than the bore it effectually prevents windage, but scoring is still found to occur to a large extent. Though called a gas-check, this really belongs to the ring class, as it is permanently fixed round the projectile.

Lyon gas-checks. Results.

The Lyon gas-checks, as at present fitted, do not give satisfactory results, as their action seems to be very uncertain.

The practice carried out for range and accuracy in January 1879 gave an increased range amounting in some cases to 350 yards, but was very irregular.

Range tables.

Range tables for use with gas-checks are not yet issued, but it is stated that on the average the use of gas-checks with the 10″ and 11″ guns at 2,000 yards range gives an increase of range of about 150 yards.

Use with time fuzes.

The question as to the use of the present service time fuzes with shell fitted with gas-checks is not yet settled, but it is stated that with 9-inch guns and under, when the gas-check acts satisfactorily, the fuze will not ignite, while if the gas-check does not act, and the flight of the shell is unsteady, the fuze will act.

With the 12·5 shell, on the other hand, it is stated that the fuzes acted satisfactorily.

Perforations have been made in the rim of some gas-checks to remedy this, but it is probable that some form of detonating arrangement will be introduced into the fuze.

*Palliser Shot and Shell.* Plate, p. 357.

Palliser projectiles.

See Treatise on Ammunition, p. 195 et seq., and Appendix, p. 21.

Palliser projectiles.

Palliser's system of manufacturing projectiles of chilled iron has been adopted in the British service, for the penetration of armour.

The successful attainment of this result depends on—

1. The metal used.
2. The mode of casting that metal.
3. The form of the projectile, or the arrangement of the metal.

The form of the projectile has been considered in the chapters on the Resistance of the air and Penetration.

Metal used.

The description of iron used in the manufacture of Palliser projectiles is selected on account of possessing in a marked degree the property that if cooled slowly the iron and the carbon have a tendency to separate, while if chilled or suddenly cooled this separation does not occur, and a white iron is produced which is intensely hard and brittle, while it possesses great crushing strength and increased density.

Density, hardness, and crushing strength are evidently adapted to the work which the projectile has to do.

Method of manufacture.

Brittleness, on the other hand, is an objection; and to reduce it as much as possible, the head only is now chilled by being cast in metal; the body is cast in sand, thus producing a metal having the properties of mottled cast iron, *i.e.*, not so hard as and more tenacious than the head.

The projectiles with bodies cast in sand are superior in penetration to those entirely chilled, because while the pressure round the head towards a centre does not test its tenacity, the base is in a very different condition, the metal there having lent its force to some extent to the head, shivers away to the front. Any increase of tenacity in the material of the base is therefore clearly an advantage; at the same time, even in the body of the projectile, it is necessary to have a hard unyielding metal. If the body was of soft metal while the head was hard, there would be considerable loss of energy on impact, owing to the setting up of the soft metal.

Strained condition of metal.

The manner in which the head is cast being the opposite extreme to annealing, which renders metal uniform and even throughout its mass, it is not surprising that its particles should be in an unnatural and constrained condition, and that on slight provocation such molecular action should take place as would cause the projectile to split; this has sometimes actually occurred, and requires special precautions in the manufacture.

This peculiar property is shown by the fact that the tip or

point of a chilled projectile is occasionally broken off by the impact of a shell or shot rolled or struck obliquely against it; for, strange as it may appear, the point which may penetrate directly through many inches of armour without injury may be fractured by a very slight transverse blow. Damaged points.

Unless the piece broken off the point be greater than 1″·5 broad or 2″·5 long, the projectile is still serviceable.

It should be noted, however, that Palliser projectiles which have been fired and recovered are not to be fired again, but are to be returned into store to be condemned and re-cast, as they are liable to break up in the bore when fired a second time. Recovered projectiles not to be fired.

The material of Palliser projectiles is so hard that they cannot be turned, and therefore must be cast as true as possible; the cast iron bush for the plug and the holes for the studs being cast in.

The head is left as it comes from the mould, and the body is slightly ground to remove any roughness and bring it to the correct gauge.

Two descriptions of these projectiles were made for guns up to the 10″ inclusive and for the 12″ 25-ton gun; they were very similar in form and construction, the only difference being that the one called a shell had a slightly larger cavity. The shot can be used as a shell when required. Shot and shell.

It has for some time been determined to have only one form of armour-piercing projectile, to be called a shell.

The discrepancies which appear in the proportions of bursting charges to weight of shell are principally owing to changes of manufacture.

The interior of the shell is carefully lacquered and the bursting charge is in a bag, in order to avoid friction against the rough internal surface.

The charge is introduced through the hole in the base, and a gun-metal (or W.I. in some earlier patterns) plug is screwed in. No fuze is used as the charge is exploded on impact against an armour plate.

Where both shot and shell are supplied to a ship the shell are all filled, but where shell only are supplied a proportion are empty.

The windage of Palliser projectiles is ·075″ to ·08″, and the clearance averages ·015″. Windage.

Some Palliser projectiles are cast with projecting bands at the base and head.

Windage. The latest pattern Palliser projectiles have these bands, which are ground to give a windage of ·075″, while the body between the bands is cast to dimensions and has a windage of ·2″.

The particulars of the latest patterns of Palliser projectiles are given in table, pp. 365–367.

Palliser shell are used from all Woolwich heavy guns.

For marking, &c. see Drill Book, pp. 73, 74.

*Common Shell.* Plate, p. 360.

Common shell. Treatise on Ammunition, p. 187 et seq.

Common shell are, as a rule, about 3 calibres long, except that for the 12-inch 25-ton gun, which for the reasons stated above (p. 353) are only $2\frac{1}{2}$ calibres, the head is ogival and struck with a radius of $1\frac{1}{2}$ diameters.

Common shell were at one time made with unloading holes in the head, but this was discontinued in 1873.

They all have two extractor holes in the head, except the 64-pr. shell which has three, and their interior is lacquered.

The thickness of the walls varies from about $\frac{1}{6}$ of the diameter in the larger natures to $\frac{1}{8}$ in the smaller; the 12″·5 common shell is, however, an exception as the thickness of the wall is $\frac{1}{4}$ of the diameter.

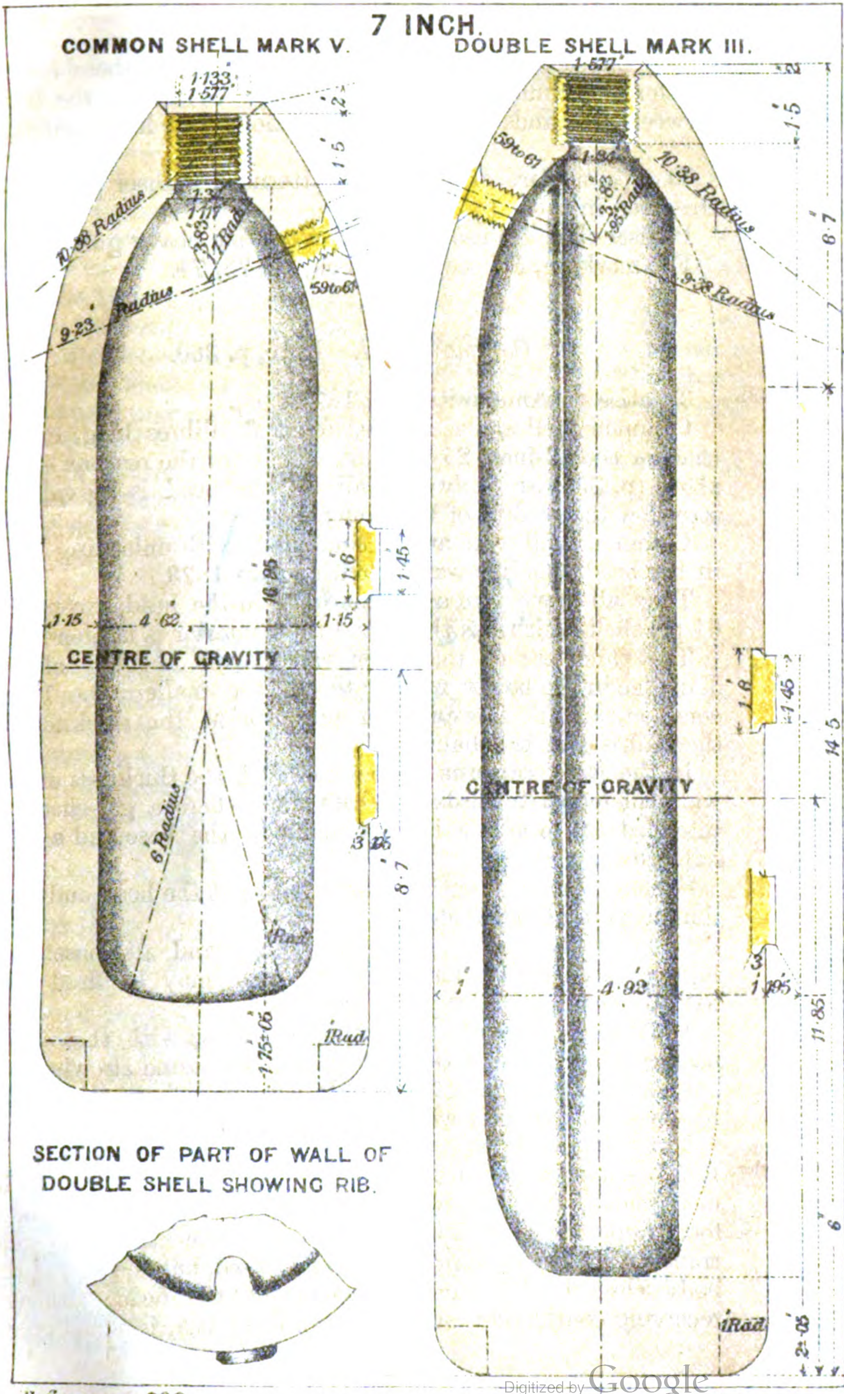
In the later patterns of common shell the thickness of the walls increases towards the base, and where a gas-check is intended to be used a hole is made in the base and a plug screwed in.

Some of the later patterns have bands at the head and base similar to the Palliser shell.

Common shell are used from all guns, and all those now supplied, except that for 12″ 35-ton gun, may be fired with battering charges. *See* p. 355 gas-checks.

Until lately the only fuze supplied for use with these shell has been the Pettman G.S. fuze which, as stated elsewhere, is only adapted for direct fire. Wood time fuzes may now however be used, and will probably be supplied.

Effect of pressure of powder. The effect produced by the pressure on the sides of a R.M.L. common shell from the gas rushing past is found to be most remarkable, the shell having a tendency to assume a form approaching that of a dumb-bell. The base being solid transversely, is not appreciably compressed, but the end of the body close to the commencement of the head, although receiving considerable support from the latter, is acted on to

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LANCERFIELD LITH 22 BEDFORD S^T COVENT GARDEN.

some extent, while the body about the middle, where it is weakest, is forced inwards, and decreased in diameter to an extent which would hardly be credited. Weakness of common shell.

The lower side of the shell in the gun appears to be convex and the upper concave; in the 10-inch the concavity has been found to be as much as 0·1 inch, and in one instance the shell in front of the rear stud was reduced from its original diameter of 9·92 inch to 9·84 inch.

The 10-inch shell altered its form, when fired, rather more than the other calibres, and experiments carried on against a target representing the side of a wooden ship indicated that a stronger shell was desirable, the walls were consequently thickened and the capacity reduced.

The shell have occasionally marks of scoring showing that they have been in contact with the iron of the gun.

The particulars of the latest patterns of common and double shell will be found in the table (p. 368).

### *Double Shell.* Plate, p. 360.

Treatise on Ammunition, p. 139. Double shell.

There are only two descriptions of double shell in the service, viz., those for the 7″ and 7-pr. guns.

The double shell for 7″ is nearly four calibres long and of increased weight. It resembles the common shell generally, but is strengthened internally by three longitudinal ribs.

It was designed for use against unarmoured ships, and owing to the large bursting charge would probably be very effective if it hit.

It is generally fired with a full charge, but with gas-checks the 22 lb. P. charge may be used. The shooting is very unsatisfactory even with the latter, the muzzle velocity being only 1161 f.s., and the mean error at 800 yards being in range 56 yards, and in direction 2·18 yards.

Owing to this want of accuracy and to the high trajectory it would be of little use over about 500 yards, unless the distance was accurately known.

### *Shrapnel Shell.* Plate, p. 361.

Treatise on Ammunition, pp. 156, 192. Shrapnel shell

The body of Shrapnel shell is of cast iron, the head of elm covered by a light shell of Bessemer metal, and struck with a radius of one diameter, except in the case of the 12·″5 which is 1½ diameters.

Over the mouth of the powder chamber is a W.I. disc rest-

apnel. ing on a shoulder and carrying a W.I. tube* which runs up the centre of the shell, and is attached at the top to a gun metal G.S. bush in the head of the shell. The tube also carries a primer (p. 133, Treatise on Ammunition).

On the disc are placed the bullets; these in heavy Shrapnel are iron† sand shot, but in light shell are made of a mixture of lead and antimony; they are fixed by running resin among them.

A tin cup is placed in the chamber under the disc to receive the bursting charge.

The side walls (except in the case of the 9-pr.) are weakened with six longitudinal grooves; and in the latest patterns the walls are slightly thicker towards the base, and there are bands at the head and base.

The chief function of the head is to cut through the air and to contain the fuze; being very light, it can be lightly attached and brings the centre of gravity of the shell, which would otherwise be too far forward to its proper position for stability.

By this method of construction very little resistance is offered to the explosion of the small bursting charge, and this being behind the bullets their velocity is unimpaired by the explosion and they keep the original direction.

uzes. The 9-sec. fuze is that now supplied for these shell and gives an average range of about 3,200 yards, but the 15-sec. fuze when supplied will give a range of about 4,000 yards.

The latest pattern for the 12″·5 gun is fitted for gas-checks.

Shrapnel are used for all M.L. guns.

Particulars of the latest patterns will be found in the table, p. 370.

## *Case Shot.* Plate, p. 361.

'ase shot requirements. The manufacture of case shot for use with rifled guns presents considerable difficulties.

When firing case shot from a rifled gun it is desirable—

(1.) That the case should not take the rifling.

If it left the bore rotating rapidly like other projectiles, the dispersion of the balls would evidently be great, and the

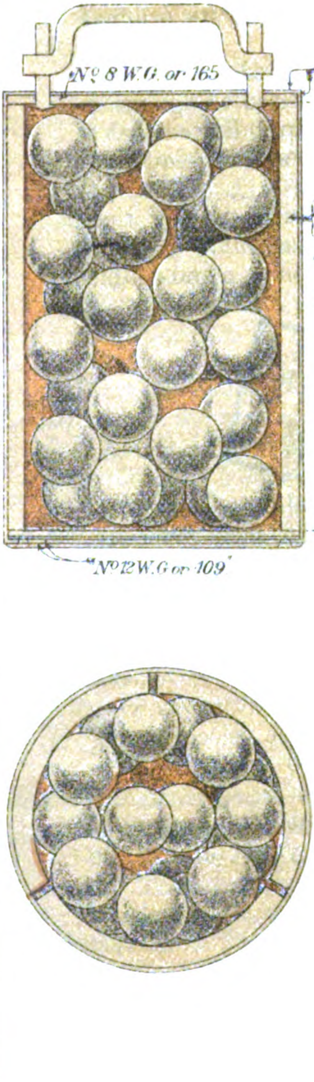
---

* In the 64-pr. a wooden tube surrounds the iron one, and in the 7 and 9 pr. shrapnel the tube is gun metal and is secured to a tin socket, which again is attached to the gun-metal bush.

† Iron shot are used from motives of economy. The others have been proved to be more effective.

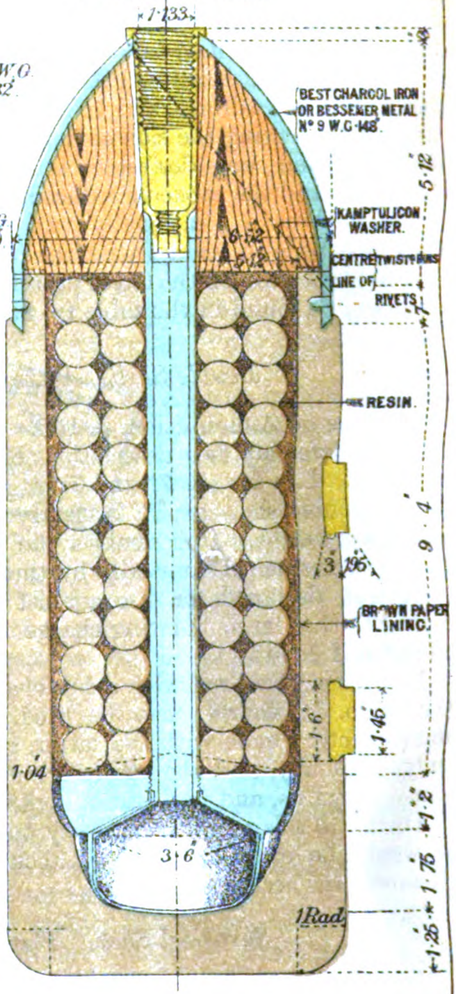
## CASE SHOT.

64 PR. MARK II.




## SHRAPNEL.

7 INCH. MARK III.




To face page 361

Dangerfield Lith 22 Bedford St Covent Garden.

effective range to the front would be correspondingly reduced.

(2.) That the case should not injure the bore or grooves.

Again all case must be strong enough for the requirements of ordinary service, and yet must break up properly on leaving the gun.

To satisfy the first two requirements it is evident that the envelope of the case must be made rigid enough to withstand the shock of discharge without setting up. **Envelope.**

In order to fulfil this condition various plans have been tried, but none can be considered satisfactory, as they increase the weight of the envelope so much, and the only effective part of the case is the balls contained.

The envelope of the old S.B. case averaged about $\frac{1}{9}$ of the weight of the projectile, while that of case for rifled guns in some cases actually exceeds the weight of balls.

The plan used to ensure sufficient rigidity in service rifle case is to line the envelope with wrought iron segments.

It seems probable that case might be made more effective by the use of steel for these linings, and by introducing smaller balls in the interstices.

With the exception of the 12″·5 case, there are practically only two classes of case shot in the service. **Two classes in service.**

Up to the 7″ inclusive, the case shot have the body made of tin in three pieces soldered longitudinally together. The bottom is of tin, soldered to the body, and has an iron *ring* riveted on outside. The top end is fringed, and the fringes bent down and soldered on to a tinned iron top. The following, however, are exceptions:—

The 9-pr., which has a tin top, covering a thin disc of wood.

The 7-pr., which has a plain tin top.

Above the 7″ the case shot has the body made of one piece of tinned iron, fringed at both ends. The bottom is an iron disc, the top is as above.

All case shot have their contents packed in clay and sand, and contain three loose wrought-iron segments as a lining, placed upon a loose wrought-iron disc at the bottom. To this rule there is one exception, viz., the 64-pr. case, which contains six segments.

For boat and field guns the case shot has mixed metal balls, while the higher natures contain 8 oz. iron sand shot, which are used for motives of economy.

Up to 7″ guns inclusive, case shot weigh about $\frac{3}{4}$ weight of other projectiles; above that calibre, less than half.

A new pattern case shot for the 12″·5 gun has been **New pattern for 12″·5 gun**

w pattern e.

brought forward but not finally approved, and differs widely from the case mentioned above.

It is brought up to the full weight of the projectile for the gun and has studs by means of which it is rotated; there is a strong iron plate both at the top and the bottom, and these are connected by means of an iron bolt, which on its lower end is screwed to carry a gas-check and nut.

The plate in the head has two iron ring bolts by which the case can be lifted.

The segments are $\frac{3}{4}''$ thick.

Case shot are supplied to all guns.

The particulars of latest patterns are given in the table, (p. 372).

## LATEST PATTERN PALLISER SHELL, R.M.L. WOOLWICH GUNS.

| Calibre, and Mark of Pattern. | Date of Approval. | Length in Inches, ± 1/16 in. per foot. | Diameters. | | Thickness of Metal. | | Weight empty, without Gas-check. | Approximate bursting charge. Shell Powder, L.G. | Weight of Filled Shell, without Gas-check. | Studs, Hard or Soft. | Distance between Centres of Front and Rear Studs. | Bands round Shoulder and Base. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Over bands and Gas-check.* | Studs. | Walls. | Base. | | | | | | | |
| | | ins. | ins. ± ·015 | ins. ± ·005 | ins. | ins. ± ·05 | lbs. ozs. | lbs. ozs. | lbs. oz. ± 1·5 per cent. | | ins. | | |
| 12″·5 III. | 15/4/78 | 33·0 | 12·425 | 12·85 | 3·25 | 3·4 | 793 11 | 11 12 | 805 7 | Soft | 7 | Yes | Three rings of studs. Gas-check. |
| 12″ 35 ton, IV. | 6/1/79 | 31·3 | 11·925 | 12·35 | 3·16 | 3·19 | 688 5 | 9 14 | 698 3 | Soft | 7 | Yes | Three rings of studs. Gas-check. |
| 12″ 25 ton, IV. | 6/1/79 | 29·2 | 11·92 | 12·35 | 2·85 | 2·85 | 586 4 | 14 0 | 600 0 | Soft | 7 | Yes | |
| 11″, Mark IV. | 6/1/79 | 28·3 | 10·925 | 11·35 | 2·9 | 3·0 | 529 8 | 6 7 | 535 15 | Soft | 8 | Yes | 11″, Mark I., was not finally approved, a number issued, capacity 9 lbs. 4 ozs. By § 2429 it was decided that only one description of Palliser projectile should be issued for the 11″ gun, viz., that described in § 2106 as Shot, Palliser, 11″, Mark I., which was then ordered to be called Shell, Palliser, 11″, Mark II. |
| 10 Mark IV. | 6/1/79 | 26·3 | 9·92 | 10·35 | 2·8 | 2·5 | 333 8 | 6 14 | 400 6 | Soft | 8 | Yes | 11″ and 10″, Mark IV., have gas-checks. |

* Limits of error in diameter over the body of Palliser projectiles increased to ± ·015, § 1899.

To facilitate identification, Palliser shell with sand cast bodies have their distinguishing numeral stamped on a rear stud in addition to being cast on the base. "E" on a rear stud denotes that the base has been tested for porous places; this mark was discontinued in 1/8/72. × and the date on a rear stud has the same signification as in common shell, table, p. 368. On the base of Palliser shell manufactured since 1872 will be found the mark Pal[r] shell, followed by the calibre, R.L., date, numeral indicating pattern, and letters indicating the nature of iron used. These letters are now not put on Palliser projectiles. Thus a 10′ Palliser shell formerly cast on the 1st January would be marked: Pal[r] shell, 10 in., R.L., ⅄ R.C. II. The letters R.C. standing for Ridsdale and Cwmbran.

The weights given above will not be found in every case to strictly correspond with those given in "Changes." Slight modifications have in some cases taken place, and the weights given above are those of the means between the high and low limits of manufacture.

### Latest Pattern Palliser Shell, R.M.L. Woolwich Guns—*continued.*

| Calibre, and Mark of Pattern. | Date of Approval. | Length in Inches, $\pm\frac{1}{16}$ in. per foot. | Diameters. | | Thickness of Metal. | | Weight empty, without Gas-check. | Approximate bursting charge. Shell powder, L.G. | Weight of Filled Shell, without Gas-checks. | Studs, Hard or Soft. | Distance between Centres of Front and Rear Studs. | Bands round Shoulder and Base. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Body. | Studs. | Walls. | Base. | | | | | | | |
| | | ins. | ins. ± ·015 | ins. ± ·005 | ins. | ins. ± ·05 | lbs. ozs. | lbs. oz. | lbs. oz. ± 1·5 per cent. | | ins. | | |
| 9″, Mark VI. | 7/6/79 | 21·45 | 8·92 | 9·31 | 2·15 | 2·0 | 244 3 | 5 8 | 249 11 | Soft | 8·05 | Yes | Small capacity shell. Gas-checks. |
| 8″, Mark V. | 7/6/79 | 19·25 | 7·92 | 8·31 | 1·92 | 2·0 | 174 12 | 4 8 | 179 4 | Soft | 5 | Yes | Have a larger base-plug in anticipation of being fitted with gas-checks. |
| 7″, Mark IV. | 7/6/79 | 16·5 | 6·92 | 7·31 | 1·685 | 1·6 | 112 1 | 2 8 | 114 9 | Soft | 4·6 | Yes | |
| 64-pr. Battering I. | 15/4/79 | 16·0 | 6·22 | 6·47 | — | — | 85 0 | 2 1 | 87 1 | — | — | No | Head slightly chilled. Hole in base. Gas-check. |

## Latest Pattern Palliser Shot, R.M.L. Woolwich Guns.

| Calibre and Mark of Pattern. | Date of Approval. | Length, ± $\frac{1}{16}$ in. per foot. | Diameters. | | Thickness of Metal. | | Weight, empty, without Gas-check. | Approximate capacity for bursting charge, shell powder, L.G. | Distance between Centres of Front and Rear Studs. | Band round shoulder and base. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Body. | Studs. | Walls (minimum). | Base. | | | | | |
| | | ins. | ins. ± ·015 | ins. ± ·005 | ins. | ins. | lbs. oz. ± ¼ per cent. | lbs. oz. | ins. | | |
| 12″ 25 ton, Mark VI. | 7/6/79 | 28·15 | 11·925 | 12·35 | 3·0 | 2·85 | 596 4 | 7 12 | 7 | Yes | Gas-checks. Base closed with a bush of W.I. and screw plug of gun-metal with key-hole. Enlarged core. Red lacquer. |
| 10″, Mark VI. | 7/6/79 | 25·8 | 9·925 | 10·35 | 2·8 | 2·5 | 400 8 | 4 0 | 8 | Yes | Same as 12″, VI. Gas-check. |
| 9″, Mark VII. | 7/6/79 | 20·85 | 8·925 | 9·31 | 2·15 | 2·0 | 244 8 | 3 12 | 6 | Yes | Same as 12″, IV. Gas-check. |
| 8″, Mark V. | 7/6/79 | 18·8 | 7·925 | 8·31 | 1·92 | 2·0 | 176 0 | 2 10 | 5 | Yes | Same as 12″, IV. Have large base-plugs, but are not yet fitted with gas-checks. |
| 7″, Mark VII. | 7/6/79 | 16·1 | 6·925 | 7·31 | 1·685 | 1·6 | 112 0 | 1 10 | 4·6 | Yes | |

Studs are all soft metal, and edge of bottom is rounded. Head struck with radius of 1½ diam. Bodies cast in sand.

N.B.—The marks on the rear stud are similar to those on the Palliser shell, table, p. 365, and have the same meaning. On the base of Palliser shot manufactured since 1872 will be found the mark Palliser shot, followed by the calibre R.L., date, numeral indicating pattern, and letters indicating the nature of iron used. These letters are now not given. Thus a 10″ Palliser shot cast on the 1st January would have been marked Pal$^{r}$ shot, 10 in., R.L. $\frac{1}{1}$. R.C. IV. The letters R.C. standing for Ridsdale and Cwmbran.

## Latest Pattern Common Shell and Double Shell, R.M.L. Woolwich Guns.

| Calibre and Mark of Pattern. | Date of Approval. | Length. $\pm \frac{1}{10}$ in. per foot. | Diameters. | | Thickness of Metal. | | | Weight empty, without Gas-check. | Approximate bursting charge, Shell Powder, L.G. | Weight of Filled Shell, without Gas-check. | Distance between centres of Front and Rear Studs. | Marks on one Rear Stud. The date refers to the manufacture of each individual shell. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bands. | Studs. | Walls. Top. | Walls. Bottom. | Base. | | | | | | |
| | | ins. | ins. ± ·01 | ins. ± ·705 | ins. | ins. | ins. | lbs. oz. | lbs. oz. | lbs. oz. | ins. | | |
| 12″ 5, Mark I. | 16/2/78 | 36·9 | 12·42 | 12·85 | 2·9 | 3·1 | — | 780 8 | 27 0 | 807 0 | 7 | — | Bands. Gas check. Three rings of studs. |
| 12″ 35-ton, Mark III. | 23/2/78 | 34·45 | 11·92 | 12·35 | 2·2 | 2·4 | 3·0 | 573 0 | 40 0 | 617 6 | 7 | Date and × ("35 ton" on every alternate stud). | Three rings of studs. Gas-check. |
| 12″ 25-ton, Mark II. | 24/12/78 | 30·0 | 11·92 | 12·35 | 1·96 | 1·96 | 3·0 | 459 6 | 37 12 | 497 7 | 7 | Date and × | Gas-check. |
| 11″, Mark I. | 3/9/72 | 34·2 | 10·92 | 11·35 | 2·15 | 2·4 | 2·75 | 506 4 | 29 12 | 536 4 | 8 | Date and × | Gas-check. |
| 10″, Mark III. | 24/12/78 | 30·55 | 9·92 | 10·35 | 1·95 | 2·15 | 2·15 | 377 12 | 20 4 | 398 4 | 8 | Date and × | Thicker walls than I. Gas-check. |

N.B.—× indicates that the studs are formed to correspond to the curve of the groove instead of being concentric with the projectiles as in previous patterns, and in all but 7″ projectiles previous to 8/3/72; it also indicates that they are of hard alloy, viz.: 7 of copper to 1 of tin. Soft alloy, viz.: 10 of copper to 1 of tin was approved for all natures on the above date. Soft studs are indicated by the date marked on them being subsequent to the above order.

On 20/12/72 it was ordered that all common shell for the Woolwich guns should be marked on the base with the day and month of casting, and calibre; the 12 being followed with "25 ton," or "35 ton," the date when finished being marked on the stud as usual.

The weights given above will not be found in every case to strictly correspond with those given in "Changes." Slight modifications have in some cases taken place, and the weights given above are those of the means between the high and low limits of manufacture. See also § 2655.

All new pattern shell have the studs swedged in, edge of bottom rounded, and are marked R $\overset{V}{\uparrow}$ L in front of one front stud, the numeral above corresponding to the mark of shell.

## Latest Pattern Common Shell and Double Shell, R.M.L. Woolwich Guns—*continued.*

| Calibre and Mark of Pattern. | Date of Approval. | Length. ± 1/16 in. per foot. | Diameters. | | Thickness of Metal. | | | Weight empty. | Approximate bursting charge, Shell Powder, L.G. | Weight of Filled Shell. Limits of Error ± 1·5 per cent. | Distance between centres of Front and Rear Studs. | Marks on one Rear Stud. The date refers to the manufacture of each individual shell. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Body. | Studs. | Width. Top. | Width. Bottom. | Base. | | | | | | |
| | | ins. | ins. ± ·01 | ins. ± ·005 | ins. | ins. | ins. | lbs. oz. | lbs. oz. | lbs. oz. | ins. | | |
| 9″, Mark V. - - | 9/12/68 | 26·75 | 8·92 | 9·31 | 1·5 | 1·5 | 2·25 | 230 9 | 19 0 | 249 12 | 6 | Date and × | Rounded base, unloading hole.* |
| 8″, Mark III. - | 9/12/68 | 24·17 | 7·92 | 8·31 | 1·335 | 1·335 | 2·0 | 166 0 | 14 8 | 180 11 | 5 | Date and × | Rounded base, unloading hole.* |
| 7″, Mark V. - - | 9/12/68 | 20·4 | 6·92 | 7·31 | 1·15 | 1·15 | 1·75 | 106 14 | 8 12 | 116 12 | 4·6 | Date and × | Rounded base and unloading hole.* |
| 7″ Double, Mark III. | 9/12/68 | 27·2 | 6·92 | 7·31 | 1·0 | 1·0 | 2·0 | 145 6 | 10 12 | 156 5 | 4·6 | Date and × | Rounded base and unloading hole.* To have gas-check. |
| 64-pr., Mark V. - | 6/77 | 16·0 | 6·22 | 6·47 | ·76 | ·76 | 1·3 | 57 6 | 7 2 | 65 8 | — | — | 3 rings of studs. Cast to gauge. |
| 9-pr., Mark V. - | 6/77 | 7·93 | 2·94 | 3·2 | ·55 | ·55 | ·6 | 8 7¾ | 0 7½ | 8 14¾ | — | — | Cast to gauge. |
| 7-pr., Mark IV. - | 16/5/78 | 6·75 | 2·94 | 3·17 | ·5 | ·5 | ·5 | 6 14¾ | 0 6½ | 7 4¾ | — | — | Copper studs. Cast to finished dimensions. |
| 7-pr., Double, Mark | 16/5/78 | 11·25 | 2·94 | 3·17 | ·5 | ·5 | ·5 | 11 2¾ | 0 15 | 12 1¾ | — | — | |

* Unloading holes discontinued, 27/1/73, § 2426, without a change of pattern.

## Latest Pattern Shrapnel Shell, R.M.L. Woolwich Guns.

| Calibre and Mark of Pattern. | Date of Approval. | Length. ± $\frac{1}{16}$ in. per foot. | Diameters. | | Thickness of Metal. | | | Number and Nature of Balls contained. | Weight of Shell empty, without Gas-check. | Weighed Bursting Charge. Pistol F.G., or R.F.G. Powder. | Distance between Centres of Front and Rear Studs. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Walls. | | | | | | | |
| | | | Bands. | Studs. | Top. | Bottom. | Base. | | | | | |
| | | ins. | ins. ± ·01 | ins. ± ·005 | ins. | ins. | ins. | | lbs. oz. ± ·15 per cent. | lbs. oz. | ins. | |
| 12″ 5, Mark I. | 17/6/78 | 35·6 | 12·42 | 12·85 | — | — | — | 284, 8 oz. | 803 1 | 2 7 | | Bands. Gas-check. |
| 12″ 35 ton, Mark I. | 25/7/73 | 33·55 | 11·92 | 12·35 | 2·2 | 2·4 | 2·25 | 368, 4 oz., or 453, 3¼ oz. sand shot. | 610 6 | 1 15 | 7 | N.B.—In future manufacture the base of shrapnel shell, for guns of 25 tons and upwards, will have their bottoms rounded, similar to other shell, *i.e.*, with a radius of 1″. |
| 12″ 25 ton, Mark III. | 11/7/73 | 29·05 | 11·92 | 12·35 | 2·04 | 2·24 | 2·25 | 276, 4 oz., or 339, 3¼ oz. sand shot. | 494 13 | 1 15 | 7 | Thicker sides, gun metal flush socket, larger centre tube, thicker diaphragm, and diaphragm and tin cup coned. |
| 11″, Mark I. | 30/6/75 | 31·8 | 10·92 | 11·35 | 1·78 | 2·24 | 2·25 | 378, 4 oz., or 465, 3¼ oz. sand shot. | 529 10 | 1 12 | 8 | |
| 10″, Mark III. | 11/7/73 | 31·13 | 9·92 | 10·35 | 1·59 | 1·84 | 1·88 | 306, 4 oz., or 376, 3¼ oz. sand shot. | 403 0 | 1 9 | 8 | Same improvements as 12″ 25 ton, III. |
| 9″, Mark III. | 11/7/73 | 25·35 | 8·92 | 9·31 | 1·34 | 1·52 | 1·7 | 374, 2 oz. sand shot | 254 0 | 1 5 | 6 | Do. do. |

N.B.—The Marks on the rear stud, and the Marks in front of one front stud of Shrapnel are the same, and have the same signification as those in the common shell, table, p. 368.

The weights given above will not be found in every case to strictly correspond with those given in "Changes." Slight modifications have in some cases taken place, and the weights given above are those of the means between the high and low limits of manufacture. Bottoms of all Shrapnel are rounded.

## Latest Pattern Shrapnel Shell, R.M.L. Woolwich Guns—*continued.*

| Calibre and Mark of Pattern. | Date of Approval. | Length. ± 1/16 in. per foot. | Diameters. | | Thickness of Metal. | | | Number and Nature of Balls contained. | Weight of Shell, empty. | Weighed Bursting Charge. Pistol F.G., or R.F.G. Powder. | Distance between Centres of Front and Rear Studs. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Body. | Studs. | Walls. Top. | Walls. Bottom. | Base. | | | | | |
| | | ins. | ins. ± ·01 | ins. ± ·005 | ins. | ins. | ins. | | lbs. oz. ± ·15 per cent. | lbs. oz. | ins. | |
| 8″ Mark III. | 11/7/73 | 22·55 | 7·92 | 8·31 | 1·11 | 1·27 | 1·5 | 300, 2 oz. sand shot | 179 8 | 1 0 | 5 | Same improvements as 12″ 25 ton, III. |
| 7″, Mark IV. | 11/7/73 | 19·0 | 6·92 | 7·31 | ·9 | 1·04 | 1·25 | 192, „ „ | 115 10 | 0 12 | 4·6 | Do. do. |
| 64-pr., Mark VI. | 6/77 | 13·72 | 6·22 | 6·47 | ·76 | ·86 | ·9 | 234, lead and antimony, 14 to the lb. | 66 0 | 0 9 | — | Cast to gauge. |
| 9-pr., Mark VIII. | 6/77 | 7·93 | 2·94 | 3·2 | ·375 | ·375 | ·45 | 28, lead and antimony, 18 to the lb. 35, lead and antimony, 34 to the lb. | 9 12 | 0 0¼* | — | Cast to gauge. |
| 7-pr. Mark, VII. | 24/3/75 | 6·5 | 2·94 | 3·17 | ·345 | ·37 | ·45 | 21, lead and antimony, 18 to the lb. 21, lead and antimony, 34 to the lb. | 7 9¼ | 0 0¼* | — | Copper studs. |

* Pistol or F.G.

## Latest Pattern Case Shot, R.M.L. Woolwich Guns.

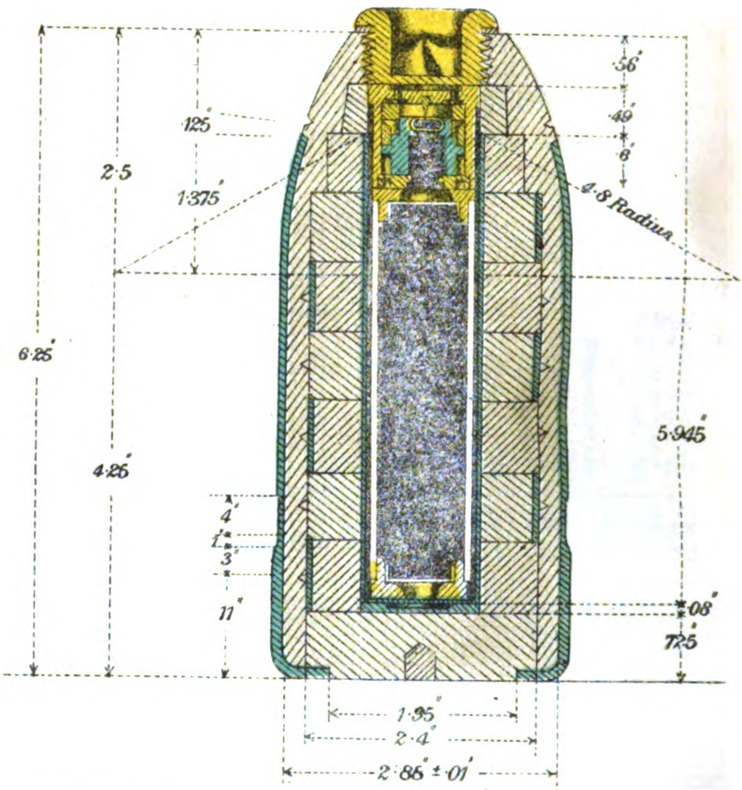
| Calibre and Mark of Pattern. | Date of Approval. | Length. | Diameter. | Number and Nature of Balls contained. | Approximate weight of balls. | Approximate weight of case, linings, coal dust, or clay and sand. | Total Weight. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | ins. | ins. | | lbs. oz. | lbs. oz. | lbs. oz. | |
| 12·5′ 38 ton, Mark II. | — | 35·97 | 12·35 ± ·03′ | 828 8 oz. sand shot | 398 8 | 404 8 | 803 0 | Gas-check and studs. |
| 12″ 25 or 35 ton, Mark II. | 5/10/72 | 11·35 | 11·88 ± ·05″ | 258 8 oz. sand shot | 129 0 | 117 0 | 246 0 ± 5 lbs. | |
| 11″, Mark I. | 15/4/72 | 10·9 | 10·88 ± ·04″ | 210 8 oz. sand shot | 102 0 | 98 0 | 200 0 ± 6 lbs. | |
| 10″, Mark II. | 31/1/72 | 9·6 | 9·88 ± ·04″ | 139 8 oz. sand shot | 69 8 | 73 8 | 143 0 ± 4 lbs. | |
| 9″, Mark IV. | 10/10/71 | 9·1 | 8·88 ± ·04″ | 113 8 oz. sand shot | 56 8 | 50 8 | 107 0 ± 3 lbs. | |
| 8″, (Gun or Howitzer), Mark II. | 1/5/75 | 8·4 | 7·885 ± ·035″ | 75 8 oz. sand shot | 37 8 | 36 8 | 74 0 ± 2½ lbs. | |
| 7″, Mark V. | 13/3/76 | 10·25 | 6·89 ± ·03″ | 71 8 oz. sand shot | 35 8 | 32 10¼ | 68 2½ ± 2½ lbs. | Case of tin in 3 pieces. Ring at bottom. |
| 64-pr., Mark IV. | 1/3/76 | 9·6 | 6·2 ± ·03″ | 50 8 oz. sand shot | 25 0 | 24 14¼ | 49 14¼ ± 2 lbs. | Case of tin in 3 pieces. Ring at bottom. Inside lining of six segments. |
| 9-pr., Mark IV. | 13/10/75 | 7·4 | 2·94 ± ·015″ | 108, lead and antimony, 16¼ to the lb. | 6 9¼ | 3 1 | 9 10¼ ± 6 oz. | Iron ring, disc, and segments. Outer case in three parts. |
| 7-pr., Mark IV. | 26/2/72 | 4·7 | 2·94 ± ·015″ | 70, lead and antimony, 16¼ to the lb. | 4 4 | 2 0 | 6 4 ± 4 oz. | Outer case in three parts. |

By § 2971 the high gauge for the diameters of R.M.L. case shot is to be the same as that for common and Shrapnel shell; and the limit between the high and low gauges will be as follows:—7″, ·07″; 8″, ·08″; 9″, ·09″; 10″ and upwards, ·1″. 9″ and above have two handles. Balls are packed in half sand, half clay.

# SHELL RIFLED BREECH LOADING SEGMENT 12 PR.
# I

*Scale ½.*

WEIGHT LBS. 10 OZS. 8 ± 4




*Diameters High Low*
*Back End....3·074....3·067"*
*Body..........3·034....3·024"*
*Commt of taper. 3·015"*
*is not to pass on the Body.*

*To face page 373.*

DANGERFIELD LITH. 22, BEDFORD ST COVENT GARDEN

## B.L.R. PROJECTILES.

B. L. R. 20-pr.

The 20-pr. is the only B.L. gun which it is at present necessary to consider.

The projectiles in use for this gun are—

1. Common shell.
2. Segment shell.
3. Case shot.

Coating of shell.

In common and segment shell rotation is given by a coating consisting of lead slightly hardened which makes the projectile of a greater diameter than the bore so that the rifling has to cut into it. This coating is attached in two ways:—

(*a.*) Mechanically, by means of undercut grooves.

(*b.*) A better plan, used with the latest patterns, is that of attaching the coating chemically by means of a zinc solder which amalgamates with the lead and iron and forms a compact and durable attachment.

The lead coating is ·05″ deep over body, and ·1″ over base, a cannelure running round the shell to take any lead stripping off the front part.

The increased diameter at base is intended—

1st. To prevent windage.

2nd. To enable the projectile to be gripped simultaneously at shoulder and base on ramming home.

3rd. To retain the grip until the base leaves the muzzle.

Uncoated portions (head and bottom) are painted black, the paint extending over the edge of the lead to prevent corrosion, &c.

Particulars of latest patterns of projectiles for 20-pr. are given in the table (p. 375).

1. Common shell. Treatise on Ammunition, p. 153.

Common shell.

These shell, with the exception of the lead coating, are very similar to those for M.L. guns and are also fitted with the G. S. bush.

The fuzes used are 9 sec. and 20 sec. B.L. time, and the Pettman G.S. percussion.

2. Segment shell. Treatise on Ammunition, p. 144.

Segment shell.

The segment shell consists of a very thin cast-iron cylindro-conoidal envelope, lined with cast-iron segments, built up in layers, having a cylindrical powder chamber in the centre. The base is closed with a cast-iron disc.

The lead coating extends from base to shoulder; it flows in between the segments and lines the powder chamber, giving

Segment shell. great weight and solidity, and also over a recess in the base of the iron disc which forms the bottom of the shell, thus retaining it in its place. The wide rim of lead at the base is the most certain way of distinguishing segment from common shell, which they closely resemble externally.

The head has been struck with various radii; the curve will be found generally more abrupt than that employed in common shell. Some are finished off with a nozzle.

The shell is strong against external pressure, while a small bursting charge opens it, and to facilitate this every segment shell has four longitudinal grooves in the interior of the head.

Burster. The bursting charge is contained in a W.I. gaspipe burster, the ends of which are closed by serge and paper discs fastened to metal rings. A wood plug covered with serge is put over this, and when it is required to prepare the shell, this is taken out and replaced by the B.L. plain fuze.

The bush is of Armstrong gauge, and the fuzes used are the E time and the B.L. plain.

3. Case shot. Treatise on Ammunition, p. 163.

Case shot. The general construction of the case shot is similar to that for R.M.L. guns, but it has solder studs to prevent its being rammed too far into the bore.

These studs are towards the rear in loading, and the case must be pressed home gently, otherwise the studs may be torn off and the case pushed past the shot chamber.

The balls are of lead and antimony, which being heavier than iron are more effective. The top consists of a piece of wood covered with tin. Under the base is an iron ring.

## Details of Latest Pattern Projectiles for 20-pr. B.L. Gun.

| Projectile and Mark. | Date of Approval. | Length, inches. | Mean Weight, full. | Bursting Charge, approximate. | Gauge of Fuze Hole. | Attachment of Coat. | Nature and Number of Segments or Balls. | Marks. | | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Head. | Coat. | Base. | |
| | | | lbs. oz. | lbs. oz. | | | | | | | |
| Common Shell, III. | 26/4/67 | 10·5 | 21 10 | L.G. 1 2 | G. S. | Zinc | — | E.O.C.* | L R ↑ L A Date III. | R.$^2$L. | Flat solid bottom; nozzle, red lacquer. |
| Segment Shell, I. | 9/5/63 | 8·1 | 19 12 | F.G. 700 grs. | Armstrong F. S. | Zinc | 56 of 1·7 oz. each, and 14 of 1·06 oz. each. | E.O.C. Z. E. | I. - - - | R.L. | — |
| Case Shot, III. | 1/11/75 | 9·3 | 20 6 | — | — | — | 239 balls, 16¼ to the lb. | On top of the case. III. W.↑D. 20-pr. B.L. | — | — | Case in three pieces, ring at bottom. Balls packed in clay and sand. 3 studs. |

* Elswick Ordnance Company.

## Rockets.

War rockets. War Rockets, plate (p. 355). Treatise on Ammunition, p. 261.

This subject is at present under the consideration of a committee, the results obtained with Hale's rockets being considered most unsatisfactory.

At present the 24-pr. rocket manufactured is Mark III., the later patterns having failed to meet the requirements of service.

The war rocket, if properly made, possesses the following recommendations:—

Advantages. It is useful for incendiary purposes, and would be still more so if the head were fitted with a shell or carcass.

Its moral effect is great, especially against savages and cavalry, and owing to the lightness of the apparatus required for firing, it can be transported easily in rough country.

Disadvantages. The disadvantages under which it labours are,—

1st. Its efficiency and safety depend on the complete contact of a very large service of composition with a thin metal case; hence it is liable to deteriorate.

2nd. Its flight is necessarily very slow, so that it is very susceptible to the action of gravity, wind, and accidental causes of deviation.

3rd. The same causes that thus make it peculiarly liable to be acted on by wind and gravity, aggravate the effect of deflection; indeed rockets have been occasionally deflected so as to come back at the people who fired them.

4th. From the fact of the composition burning away during flight, the position of the centre of gravity is constantly changing.

Cause of motion. The motion of the rocket depends on the well-known law that "action and reaction are equal and opposite."

The gas moves in one direction with a great velocity, and the rocket in the other with a lesser velocity, and we have by equating the momenta or quantities of motion, the mass of the gas multiplied by its velocity equal to the mass of the rocket by its velocity.

The principle of motion being understood, it is necessary to pass on to the means by which a projectile of such length is kept point first.

Two methods have been employed:—

1. By means of a long stick attached; this had many objections and is now superseded by
2. Giving the rocket rotation by inclining the vents.

Hale's 24-pr. *Hale's War Rocket*, 24-*pr.*—*See* plate, p. 355, and Drill Book, pp. 81, 82.

The head is of cast iron, plugged with wood, and riveted on to the body. This is made of mild steel, the seam being riveted and brazed. The body is corrugated longitudinally in three places to give a good hold to the composition, and is tinned and painted inside and out. The base is closed by an iron disc, secured to the body by screws, and tapped to take the tail piece. Hale's 24-pr.

This is of cast iron, cupped out inside, and contains three conical vents, the larger part of the cone being towards the interior. These vents are cut away on one side, and the gas rushing out and finding less resistance on one side of the vent than on the other, causes the rocket to rotate. The vents at the base are protected by a canvas cap, secured with twine.

The rocket composition is driven by hydraulic pressure, and bored out in a conical shape, so as to expose a large surface to the flame, and so to form a sufficient volume of gas to start the rocket.

The above description is that of Mark III., as now made.*

Approximate ranges, given in a late W. O. Memorandum (7th Nov. 1879), are as follows:—" S.S. rocket tube, 10° elevation, range 2,300 yards; 15° elevation, range 2,700 yards. " It is to be noted that there will sometimes be a variation in " range of 400 yards on each side of mean." Ranges.

It will be observed that these differ widely from the ranges given in Text Book on Ammunition, p. 271; they also differ from the ranges given in R.A. Handbook for Field Service.

If it should be required to land a rocket brigade, it will be necessary to fit a tripod with a socket, into which the stanchion of the S.S. rocket machine ships. This socket should be fitted with a clamp, and the tripod should be made low and with one leg projecting well to the rear. Use on shore.

All Hale's rockets should be carefully examined at frequent intervals, particularly along the seam and round the rivets. They must be kept in as dry a place as possible, and should be carefully handled. Examination.

Rockets occasionally are found to "puff" in flight; this may be due to the sudden or irregular burning of the composition, or to the vents becoming choked. It is generally injurious to the flight of the rocket, and is sometimes developed to such an extent that the rocket bursts, this having on some occasions happened before the rocket left the tube.

*The Signal Rockets* in the Service are of one nature, viz., 1 lb. Signal rockets.

* *See* Appendix, p. 504.

Signal rocket. The case and head are made of strong paper, the former containing the rocket composition, and the latter the composition for the stars; the bottom of the case is choked, so as to form a single vent in the axis, and the stick is attached to the side of the rocket.

They are fired vertically, or nearly so, either from a tube supplied for the purpose, or by being rested against the hammock netting, or simply by hand. When the composition is consumed the bursting charge explodes the head and ignites the stars, which in falling produce a brilliant light that can be seen at a great distance.

## Friction Tubes, Lights, &c.

### Treatise on Ammunition, Chapter VIII.

Friction tubes, Quill. *Quill Friction Tubes* are used in the Naval Service for the ignition of all gun charges, and also for firing rockets.

The quill is driven with mealed powder pierced up the centre with a fine hole (to expose a large surface of the powder to *immediate* ignition), and a roughened copper friction bar is passed through it, above the mealed powder (on the *top* of which the detonating composition is placed); the head is then filled with gunpowder and clay and closed with shellac putty to protect the composition from damp. The head of the tube is kept in place during the pull of the tube laniard by a leather loop, which goes over the tube pin in the gun.

They are of two sizes—

*Short*, $2\frac{3}{4}''$ long, for guns under $10''$ calibre, except when firing reduced charges from $8''$ and $9''$ guns, or when using waterproof cartridges; it is also used for the signal rocket tube and with lifebuoy portfires. This tube will strike fire through two thicknesses of serge when in a vent $14''$ long.

*Long*, $4''$ long, is formed by cementing two quills together; it is used for guns of $10''$ and upwards, for reduced charges of $8''$ and $9''$ guns, and for firing Hale's rocket. It will strike fire as above at a distance of $21''$.

Copper. Copper tubes resemble generally in their manufacture the quill tube above described, but have no loop for the friction pin.

There is a special 5-inch tube, with a copper wire attached to keep it from flying, issued for use with waterproof cartridges; a small lanyard is hooked on to the wire and hitched on to the gun carriage.

Keeping qualities. The action of friction tubes is generally very certain when new, but their keeping qualities are not very good.

Friction tubes.

In order to assist the War Department as far as possible in remedying the defects of gun tubes, of which reports are frequently received, reports of failures of gun tubes are always to be accompanied by the "operation paper" of the cylinder from which the tubes were taken; a statement being made at the same time as to whether the cylinder was opened for the occasion of using the tubes, or, if not, how long the cylinder had been opened.

In preparing for action, any boxes of tubes which may have been previously opened should be thrown away, and only tubes from fresh boxes employed.

Port fires, common.

*Common Portfires.*—The common portfire is formed of stout paper rolled into a cylinder, about 16 inches long, and $\frac{3}{4}$-inch in diameter, filled with portfire composition. The paper is turned in at one end to form a bottom; the other end is primed with powder paste.

It burns from 12 to 15 minutes, with great local heat, and is used for incendiary purposes.

They are supplied in bundles of 12, with a brown paper cap over the primed end, and are packed in metal lined cases with signal rockets.

Life Buoy.

*Life Buoy Portfires* consist of seven pieces of portfire fixed to a gun metal plate by copper wire. The first $3\frac{1}{2}''$ is driven with quickly burning composition, to prevent its being extinguished on falling into the water, and it has also been found necessary to use a quickly-burning composition in the last short length as the portfire sometimes got choked and extinguished at this point. They are primed by placing a quill friction tube in a gun-metal socket opposite the first length.

The portfire is intended to indicate the position of the life buoy at night, and burns from 20 to 24 minutes.

They are supplied unpacked.

Lights, Long.

*Long Lights* consist of a stout paper case, about $9\frac{1}{2}$ inches in length, and $1\frac{3}{4}$-inch in diameter, left open at one end about 2 inches for fixing the handle into; the remainder of the case is driven with long light composition, the top strengthened by a band of tin, and covered with a metallic cap.

They are ignited by means of a detonating primer placed in a hole in the tin band, and burn from 5 to 6 minutes, with a bright white light.

They are supplied in tin cylinders containing 4.

Signal.

*Signal Lights* are similar in construction to the long lights, but are much shorter. They burn 1 minute, with a very brilliant light, from the fact of their containing magnesium and paraffin in addition to the long light composition.

They are supplied in tin cylinders, the same as long lights.

Primers. *Detonating Primers* consist of a copper cylinder with a collar at one end, into which is inserted a thick piece of copper wire, wedge shape at one end, roughened on both sides of the wedge, and smeared with detonating composition. The cylinder is flattened round the wedge, woolded with copper wire, and covered with paper.

They are used for igniting long and signal lights; and are supplied in tin boxes, 5 or 10 in each.

Match, Slow. *Slow Match* consists of slightly twisted hemp, soaked in a boiling solution of water and wood ash.

It serves as a means of carrying ignition for incendiary purposes, and burns at the rate of 1 yard in 8 hours.

Quick. *Quick Match* consists of cotton wick of different thickness, boiled in a solution of distilled water, gum arabic, and mealed powder.

It burns at the rate of 1 yard in 13 seconds in the air; when enclosed in a small tube its action is instantaneous.

It is only supplied on special demand.

## Small Arm and Machine Gun Ammunition.

Treatise on Ammunition. Chapter XV.

### *Small-arm.*

Martini-Henry. Ball. Martini-Henry Ball Cartridge. Mark III. Plate, p. 380. Charge 85 grains R. F.G.[2] Bullet: weight 480 grains, length 1·27″, diameter at shoulder ·439″, at base ·45″.

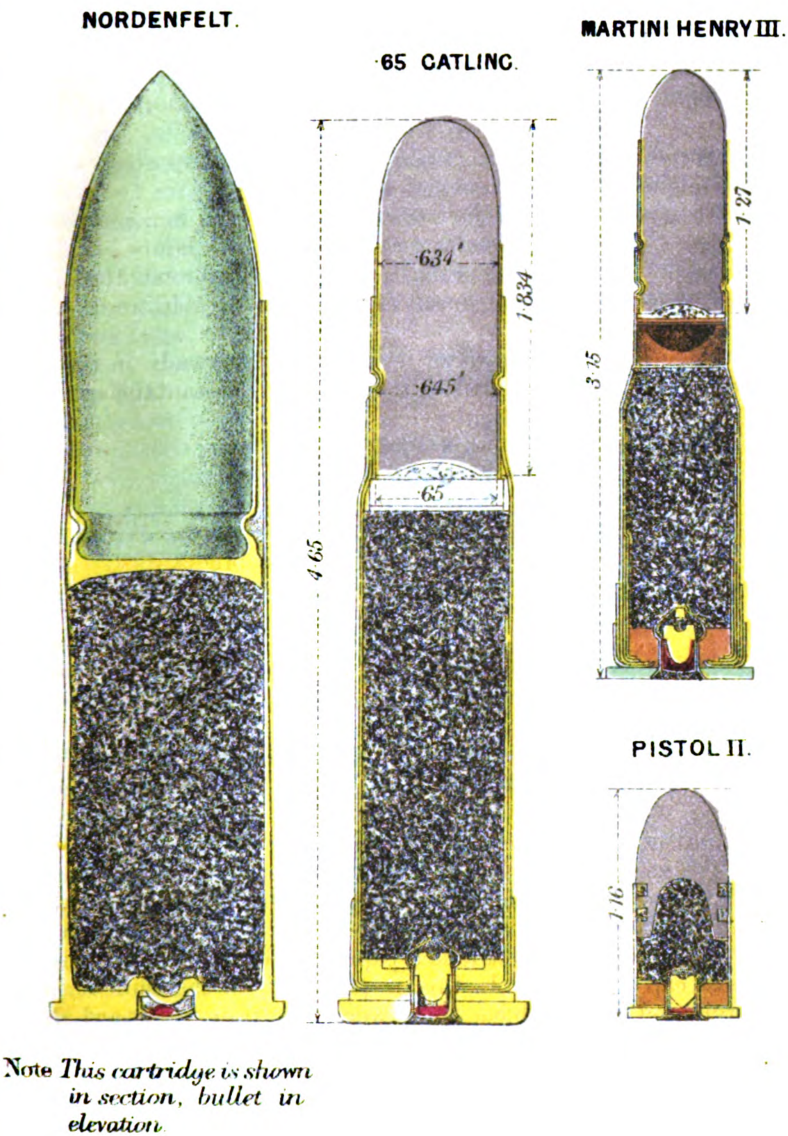
The bullet is made of lead hardened with tin, it has a slight hollow in the base, and two cannelures into which the cartridge is choked. It has two turns of fine paper wrapped round the lower part and lubricated.

The case is of ·004″ brass, and is lined with tissue paper where the powder charge comes. Two turns and a half are taken, and the base is strengthened by additional brass cups and an iron disc. Inside is a papier mâché pellet containing a brass cap chamber. In this is placed, from the outside, the anvil and cap. Above the powder is a thin millboard disc, then a beeswax wad, and two more millboard discs under the bullet.

These cartridges are found to stand rough usage and wet well, but a damp hot climate soon affects them if the air-tight tin box in which they are supplied has been opened.

## SMALL ARM AND MACHINE GUN AMMUNITION.

*Full Size.*




To face page 380.

Dangerfield Lith 22 Bedford St Covent Garden

They are very safe, as it is almost impossible to explode them in a mass. **Martini-Henry. Ball.**

Three patterns of M.H. ammunition have been issued, but Mark III. is that usually met with, and is the present service pattern, Mark IV. not being issued.

The M.H. cartridge, though somewhat similar in shape to the ·45 Gatling, is not interchangeable with it, the dimensions not being the same. It is found not to answer in machine guns.

It is probable that the introduction of machine guns and, possibly, of magazine rifles will before long necessitate the introduction of a solid drawn case instead of one coiled as at present. This would have many advantages.

*Blank Cartridge Mark IV.*—Blank cartridge is suitable for either M.H. or Snider. It has a paper case and the powder is loose. **Blank.**

*Pistol.* Plate p. 380.—This cartridge is a small brass cylinder (·01″ thick) with base attached, as in M.H. There are no base cups. **Pistol.**

The bullet is pure lead, and weighs 225 grains. It is lubricated with beeswax, and has two cannelures. Charge, 13 grains of pistol powder.

There is a small loose coil of paper between the powder and the metal of the cylinder.

Mark II. has the base disc of brass; Mark I. of iron.

There is now no cotton over the powder.

## *Machine Gun.*

*Nordenfelt Cartridge.* Plate p. 380.—The case is of solid drawn brass. There is no anvil, but a small boss in the chamber instead. **Nordenfelt.**

The powder charge weighs 625 grains, is composed of special powder manufactured by Pigou, Wilkes, & Co., and is pressed into the cartridge, care being taken that it shall always occupy the same space. The effect of this pressure is to break up the weaker grains and to form a hard solid mass of dust with grains interspersed.

It is not known exactly what effect this method has on the regularity of combustion.

The bullet weighs 7¼ oz. and is of steel, the point being hardened, the base softer, with a cannelure into which the envelope is choked, and also with several radial cuts into which it is set on firing.

Nordenfelt. The space between the bullet envelope and the inside of the cartridge case is filled with pure beeswax as a lubricator.

The rotation is given by the envelope, which is made of very thin brass, the base shaped into the form of a gas-check, and the front end carefully turned over the shoulders of the bullet. This is sufficient to keep it from stripping on passing through the air, but does not interfere with the penetration.

·65 Gatling. ·65 *Gatling*. Plate, p. 380.—The cartridge is a coiled case made of sheet brass ·01″ thick. The construction resembles that of the M.H. cartridge, differing only in minor details.

The bullet is of the same alloy as the M.H., and weighs 1,422 grains (about 3¼ oz.). The charge is 270 grains R.F.G².

A steel bullet and a lead coated steel bullet have been tried for service against torpedo boats, but are not yet adopted.

·45 Gatling. ·45 *Gatling*.—This is of the same shape as M.H. cartridge, but is a solid brass cylinder and the base is made in one piece with the case.

The cap arrangement is similar to that used in the Nordenfelt cartridge and shown in the plate. The cases are not lined with paper, but lacquered. The charge, bullet, and mode of filling are similar to the M.H.

## Fuzes.

Fuzes. See Treatise on Ammunition, p. 21, and Drill Book, p. 77.

All S.S. shell are fitted with G.S. bush, except the 20-pr. segment, which, as remarked before, is Armstrong gauge.

Fuzes are classed under two heads :—

1. Time.
2. Percussion.

## Time Fuzes.

### *General Remarks.*

Time when used. Where the distance is accurately known, and it is desired to burst the shell in the air, time fuzes are the best to use.

This is the case when firing shrapnel at bodies of men or boats, as, owing to the construction of the shell the bullets retain their direction, and to obtain the best effect the shell should be burst in the air some distance in front of the object. *See* p. 262.

When firing against unarmoured ships or fortifications, or where the distance is not accurately known, percussion fuzes should be used.

As regards the use of time fuzes, the following disadvantages are incurred :— **Disadvantages.**

1. The distance must be accurately known or the effect of the shell is frequently lost either from bursting too soon or from a blind fuze.
2. The same effect may be produced by irregularity in burning, owing to deterioration in the fuze or atmospheric conditions.
3. They require fitting.

The plan introduced with the Armstrong F.S. shell many years ago, of always using a percussion fuze in the shell, so that in the event of failure in the time fuze there was still a possibility of effect was a good one, but it has not been further developed with other shell as it would entail the use of metal time fuzes instead of wood fuzes which have been adopted as a measure of economy.

**Advantages of metal fuzes.** Taking into consideration the chances of failure of a wood time fuze, the value of the projectile with which it is employed, and the small number used yearly in peace time, it is probable that the use of a metal fuze would be in reality more economical, at least with heavy guns. If this plan were adopted combination fuzes might be made, and the additional disadvantages peculiar to a wood fuze would be obviated. These are—

**Disadvantages of wood fuzes.**

1. For the conditions of sea service no time fuze can be considered efficient which cannot be fitted on the gun deck, and to be able to do this with common shell containing a large bursting charge it is necessary for safety that the fuze should be of such a nature that it can be adjusted without removing it from the shell.
2. No one at the gun can see whether the fuze is correctly fitted.
3. Once fitted it cannot practically be altered.
4. It is not strong, and cannot be firmly fixed.

The result of these disadvantages is that unless the range is known some time beforehand, and is not likely to alter, time fuzes could never be used with common shell from heavy guns in ships, as the time required to fit and pass up from below a broadside of shell would be considerable, and once fitted they cannot be altered without passing them below, as it is taken for granted that it would be most unsafe to open them on the gun deck.

## *Wood Time Fuzes.*

**Wood time fuzes.** Seasoned beech wood is used as the material of the body which is made conical, this shape having an advantage over the

cylindrical form, as there is less risk of the fuze setting back into the shell on the shock of firing, and they are more easily inserted.

Channels.

The fuze composition is contained in a channel which is central or eccentric according to the number and position of the powder channels which are used in all fuzes except the 20 second. They are essential in fuzes for shrapnel shells, where the bursting charge is not immediately surrounding the fuze, and consequently a strong flash is required; they also would be necessary in the case of common shell when the fuze is bored short, because the flash would be obstructed by the side of the fuze hole.

If only one powder channel were used, it is obvious that there would not be room for the side holes to be bored in a fuze reading to tenths of inches of fuze composition, the diameter of each side hole being 0″·125. By the use of two powder channels we are therefore enabled to graduate the fuze just twice as finely as we could do with one powder channel, and in the 15-second fuze, for similar reasons there are six. The powder channels are connected at the bottom by a groove filled with quickmatch, to cause them both to act at the same time, giving a strong downward flash.

Protection from accidental ignition.

In all time fuzes the last hole in the row is bored through into the composition to ensure the action of the fuze when fixed in the shell without preparation.

In all time fuzes it is desirable that they should not be liable to ignition before they are "uncapped," as otherwise fuzed shell would be endangered by sparks, or by a neighbouring explosion, this is attained in most of the M.L. fuzes by a copper and tape strip covering the priming, while B.L. fuzes are protected by the papier mâché wads and copper discs covering the escape holes, and as regards the detonating arrangement by a safety pin in the later patterns.

Ignition.

It is important that the fuze (except, of course, in the case of B.L. guns) should not be uncapped till the shell is placed in the bore.

The heads are closed, otherwise they would burn much quicker on account of the pressure of the air, and would be more likely to be extinguished on graze.

Ignition.

In M.L. guns the fuze is ignited by the flash of the charge; for the effect of gas-checks on this point (see p. 357). B.L. fuzes are fitted with a detonating arrangement in the head.

In all time fuzes a small hole is drilled in the top of the column of fuze composition; this renders ignition more certain.

The bottom of this hole is taken as the zero from which the fuze is graduated.

The channel containing the fuze composition has a paper lining, as in hot climates the wood was found to shrink away from the composition, leaving a space and causing prematures.

Fuze composition burns at the rate of about 1 inch in 5 seconds; mealed powder at the rate of 1 inch in $2\frac{1}{2}$ seconds, *i.e.*, twice as fast as fuze composition. **Time of burning.**

These fuzes are found to deteriorate by keeping, and have a tendency to burn long.

Fuzes burn at sensibly different rates when fired from different guns; as a rule they burn quicker from large than from small guns, probably because in the former the velocity of projectile is kept up better.

The proof records of R.L. show that the average time of burning of the 9-seconds M.L. fuze is—

| | | |
|---|---|---|
| 10·4 | seconds from the | 9-pr. gun. |
| 9·3 | „ | 64-pr. gun. |
| 9·0 | „ | 12 in. 25 ton gun. |

They also burn quicker when rotated than when at rest. Thus a fuze, whose mean time of burning when at rest is 10·1 seconds, is found to burn 9·74 seconds when rotating at the rate of 151 revolutions per second.

The so-called 9-seconds fuzes really burn 10 seconds when at rest.

## *Description and Marks of Wood Fuzes.*

It is important to have a clear idea of the difference between the various Marks of M.L. fuzes, as they cannot be used indiscriminately. The difference between Marks I. and II. is in the amount of priming and in the manner of protecting it. The priming in Mark I. was found not to ignite with certainty when small charges were used, therefore Mark II. was introduced, having an increased quantity of priming wrapped round the groove in the neck of the fuze, this caused a projection, over which the copper strip used in Mark I. could not be placed, so Mark II. has the priming covered with a tape band only, and is not so well protected against risk from fire, when placed in the shell, as Mark I.; it has, however, the advantage of acting with small charges, such as are used with boat or field guns. It was obviously an inconvenience to have two fuzes, one for light and the other for heavy guns, therefore Mark III. has been introduced. **Marks of wood fuzes.**

Fuzes of the Mark III. pattern are more certain of ignition, will be less likely to cause prematures, and stand climate better than the previous patterns.

Regulations for issue. The following are the regulations for the issue of the various Marks of 5, 9, and 20 seconds M.L. fuzes.

Fuzes of Mark I. will be retained in the service, and supplied to the Navy for use with all rifled M.L. guns, other than boat and field guns.

Mark II. will, until the store is exhausted, be supplied for naval service for boat and field guns.

Mark III. is for boat and field guns.

Marks II. and III. are supplied to the Navy when Mark I. is not available.

The 15-second fuze is intended, however, to supersede both the 5 and 9-second fuzes.

5-second. *5-seconds M.L. Fuze, Mark III.*—See Plate opposite and Drill Book, pp. 78 to 80 and Plate at end. The central channel is driven with 2·7″ of mealed powder, and is bored down ·7″ from the top, the bottom of this hole being exactly ·2″ above the top side hole which is numbered 1, and 2″ from the bottom side hole which is bored into the composition.

In addition to the column of composition are two small powder channels filled with pistol powder; opposite to and communicating with each of these powder channels is placed a row of side holes, ten in number, bored horizontally from the outside of the fuze; the holes in each row are 0·2″ apart, the holes in one row not being opposite to those in the other row, but dividing the spaces, thus indicating respectively odd and even tenths of composition; the two bottom side holes are drilled through into the composition, and are filled with quickmatch to ensure the ultimate action of the fuze in case of imperfect boring or non-preparation of the fuze. The holes are numbered 1, 2, 3, &c. in one column, and 1·5, 2·5, &c. in the other. These holes correspond exactly in position with those in the 9-sec. fuze, and are numbered like them in order that the same figures on either fuze may represent the same time of burning. In the 5-sec. fuze each interval represents approximately one quarter second, the integral figure in each case referring to half seconds.

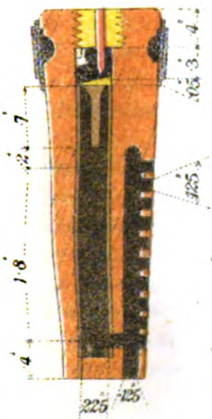
The upper part of the composition bore is closed by a metal plug screwed permanently into it flush with the top of the fuze. From the centre of this plug projects downwards a copper pin, round which are looped small pieces of quickmatch, the ends passing through two escape holes, which are provided in the side of the head of the fuze for the escape of the flame from the burning composition.

The quickmatch is laid in a groove round the head of the fuze, and is covered with first a tape band then a strip of thin

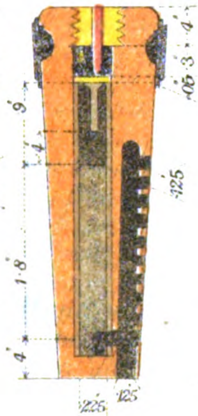
# FUZES FOR M.L.R. ORDNANCE.

## WOOD TIME.

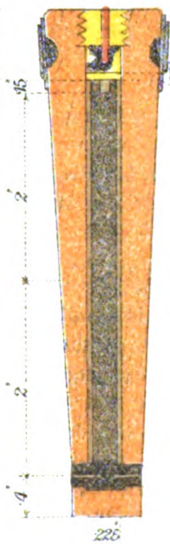
5.Sec. MARK III.



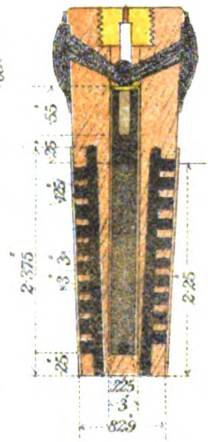
9.Sec. MARK III.



20.Sec. MARK III.



15.Sec.

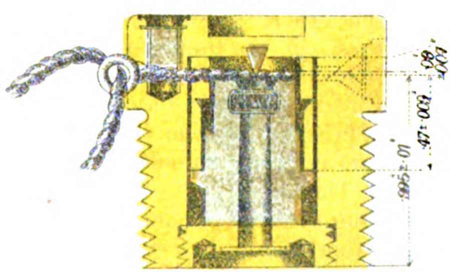


## PETTMAN PERCUSSION.

C. S. MARK II.

## R. L. PERCUSSION.

MARK II.



Copper.
Gun metal.
Wood.
Brown paper.
Lead.

*To face page 386.*

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sheet copper, which is covered with another tape band, one end of the copper band on either side being left exposed and loose. 5-second.

For details as to preparation see Drill Book, p. 79.

The flash of the discharge ignites the quickmatch, and the flame passing through the escape holes sets fire to the column of composition, which burns down until it reaches the hole which has been bored into, when the flame ignites the powder in the powder channels, and thus fires the bursting charge. Action.

9-*seconds M.L. Fuze, Mark III.*—See Plate, p. 386, and Drill Book, pp. 78 to 80 and Plate at end. This fuze contains 1″·8 fuze composition, above which is driven a pellet ·9″ long of mealed powder, ·5″ of this being perforated, thus leaving ·4″ (equal in time of burning to ·2″ fuze composition). This is done to obviate the risk of cracking the composition when boring for short ranges, a result liable to occur if there were only ·2″ of composition over the top side hole. The construction and size of this fuze are identical with those of the 5-seconds fuze, except that fuze composition is used instead of mealed powder, and consequently the intervals approximate to half-seconds only. 9-second.

Preparation and action are similar to that of the 5-seconds fuze.

20-*seconds M.L. Fuze, Mark III.*—See Plate, p.386, and Drill Book, pp. 78 to 80 and Plate at end. It has 4″ of fuze composition, on the top of which is ·15″ (in Marks I. and II. ·1″) of mealed powder, through which the small hole to ensure ignition is bored. It differs from the fuzes already described in that it has no powder channels; but the arrangements as to priming, paper lining, &c., are the same as in other M.L. fuzes. It has two pellets of mealed powder, pierced, as shown in the section, to carry the flash from the bottom of the fuze into the bursting charge of the shell. 20-second.

Commencing with two inches of composition, the lower part of the fuze is marked with a spiral row of side holes ·2″ vertically apart, and numbered in even numbers from 20 to 40, so that the intervals approximate to seconds.

When the fuze composition becomes ignited, it burns out of the two escape holes until it reaches the hole bored into, when the flame at once passes into the shell.

This fuze cannot be used with shrapnel shell.

15-*seconds Fuze.*—See plate, p. 386, and Drill Book, p. 78 to 80 and Plate at end. This fuze in general principles of construction, and in external dimensions, resembles the 5 and 9 sec. Mark III., M.L. fuzes. It has, however, the composition 15-second.

15-second. channel in the centre, driven with 2″ of slow burning composition (1″ in $7\frac{1}{2}$ seconds). Above this is a ·8″ pellet of mealed powder bored so as to leave 25″ solid. There are six powder channels connected at the bottom by quickmatch placed in an annular groove and pressed into the bottom of each channel. The bottom hole of one channel is bored through and threaded with quickmatch. The paper scale gives intervals approximating to half seconds and quarter seconds of time (the same half second unit as in the other time fuzes).

This fuze burns about 15 seconds at rest; when fired in rifled shells 13 to 14 seconds only. It is intended eventually to supersede the 5 sec. and 9 sec. M.L. fuzes, and will be available to ranges of about 3,500 yards from the 9-pr. gun and 4,000 yards from heavy guns.

There is also a 30 second fuze, but it has not yet been adopted for S.S.

B.L. wood fuzes. *9-second and 20-second B.L. Fuzes, Mark II.*—See Plate opposite and Drill Book, pp. 78 to 80 and Plate at end. These fuzes are exactly similar to the corresponding M.L. fuzes with the exception of the head.

The arrangement for lighting the fuze is contained in the top of the fuze, about one inch space being left above the composition bore; the upper part of this space is slightly enlarged and fitted with a metal detonator.

Detonating arrangement. The detonator body contains at the top a small hammer with a projecting stem of a mitre shape; the hammer is held in its place by means of a copper suspending wire; in the bottom of the detonator body is a small recess containing cap composition, a small hole through the centre of the recess leading to the fuze composition bore.

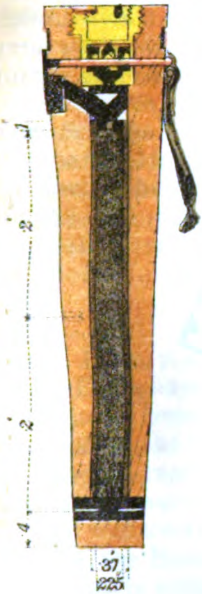
There are three escape holes fitted with quickmatch beneath the detonator; they are closed, so as to prevent the accidental ignition of the fuze, but at the same time to give free egress to the flame of the fuze when lighted.

The head of the fuze is strengthened by six turns of copper wire woolded round it.

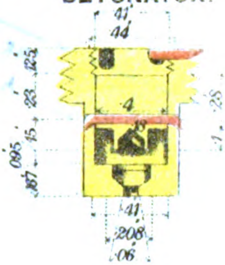
To guard against injury to the suspending wire and possible accidental ignition of the fuze, it is fitted with a safety pin of brass wire, which passes through the fuze and detonator body close beneath the stem of the hammer, the outer end of the safety pin is fitted with a loop, to which is attached a braid lug for withdrawing it; this braid is laid down by the side of the fuze, and a slip of paper cemented over the head of the safety pin and round the fuze, and painted over with black paint to secure from damp.

# FUZES FOR B.L. ORDNANCE.

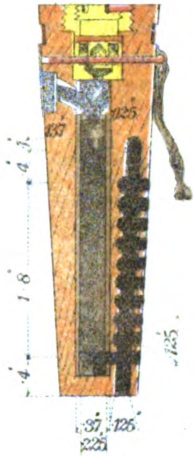
**20 Sec. MARK II.**



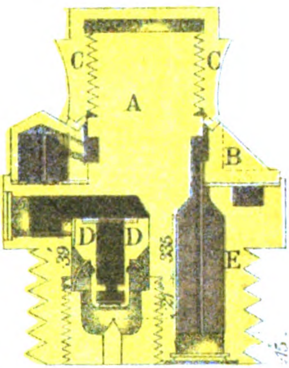

**ENLARGEMENT OF DETONATOR.**




**9 Sec. MARK II.**

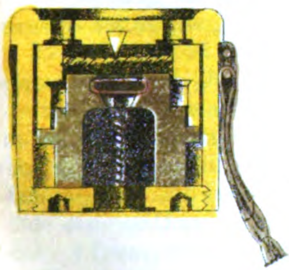



**E. TIME. MARK III.**




A. *Body of Fuze.* | C. *Cap.*
B. *Collar.* | D. *Gun metal pellet.*
E. *Blowing Chamber.*

**PERCUSSION, PLAIN.**



*To face page 388.*

For fitting B.L. fuzes see Drill Book, p. 80. Marks I. of these fuzes had no safety pin, and were fitted with a washer at each end to preserve them from concussion.

Action.

On the shock of discharge, the hammer in the detonator body by its inertia shears the suspending wire, its stem entering the recess and firing the detonating composition, which ignites the priming and quickmatch; the gas generated opens the escape holes by blowing out the discs of copper and papier mâché, the composition burns regularly till it reaches the hole at which the fuze is bored, and the flame then fires the bursting charge of the shell.

It is not known whether these fuzes are strong enough to be used in shell fired from heavy guns, but the use of gas-checks will probably necessitate the introduction of some detonating arrangement in M.L. fuzes.

*Armstrong, E. Time Fuze.*

Armstrong, E. time.

See Plate, p. 388 and Drill Book, pp. 70 to 80 and Plate at end. There have been various patterns of this fuze, but only one is now issued, which may be known by the word "cap" stamped on the base of the fuze.

This fuze represents a large class of time fuzes employed by continental nations with Shrapnel shell.

Advantages.

The construction is complicated, its cost is about double that of the Boxer B.L. time fuzes, and many defects existed in the early patterns, which brought the fuze into disrepute, but in its present state it has several important advantages over the wood time fuzes. It can be set to very small intervals, a point of the greatest importance; it can be altered again after setting; it is open to inspection, so that the officer or the No. 1 of a gun can see that it is correct, instead of depending on those employed in preparing shells; it can also be set at the gun.

Description.

Both body and nut in the last pattern (E. III) are made of gun metal, and the graduations for length of fuze in inches and tenths are marked on the metal rim instead of on paper, as in former patterns. The pellet, which is supported by a brass cup, is filled with R.F.G. powder, secured by thin paper fastened on its base; the detonator in the head consists of cap composition, which in those lately made is covered by a disc of brass, ·001″ thick.

The fuze composition is pit mealed powder pressed into a ring or groove which runs round close to the exterior of the fuze body; this composition burns at the rate of 1 inch in 2

Armstrong E-time.

seconds, and, owing to a metal stop, can only burn in one direction, *i.e.*, from left to right.

A leather washer and movable gun-metal collar cover the ring of composition. At one part of the collar a channel, primed with mealed powder driven and pierced, and marked on the outside with an arrow, communicates with a groove round the neck of the fuze, which contains mealed powder; this groove is connected by a channel with the blowing chamber, which is primed with mealed powder, driven and pierced; a small brass disc closes the chamber.

The movable collar is kept in its place by a nut which screws on to the neck. The body has a small hole in the side to fit a projection in the Armstrong key used in screwing in the fuze. See p. 80, Drill Book.

Stress must be laid on the importance of screwing the nut tightly home when the fuze is adjusted, otherwise the washer will not be tightly pressed down on the ring of fuze composition, and a premature may occur.

Action.

On firing the gun the brass cup is crushed in, the pellet strikes the needle, which explodes the detonating composition, the ring of fuze composition is ignited by the flash, and burns till it comes to the channel marked by the arrow head, leading to the groove in the neck primed with mealed powder, the flash is then instantaneously conveyed into the blowing chamber, and thence into the shell.

Percussion fuzes.

## PERCUSSION FUZES.

### *General Remarks.*

General remarks.

There are at present three kinds of percussion fuzes supplied for S.S., viz., the Pettman G.S., for use with 64-pr. and upwards, and for 20-pr. B.J. common shell, the R.L. for use with field and boat guns, and the B.L. plain for 20-pr. segment.

Besides these there are two other percussion fuzes, of which a short account will be given, viz., the sensitive fuze for use with very small charges, and the delay action, for use in the base of a battering shell, fired from siege guns against masonry.

Use.

Percussion fuzes are employed for two distinct purposes; they are used in shells intended exclusively to act against solid obstacles, such as wooden ships, earthworks, moderately thin brick or stone walls, or buildings and material generally; and they are also used in shells employed against boats or troops in the field.

Against obstacles.

For the first purpose it is desirable that the fuze should only act on direct impact, and a very instantaneous action is

not required. It will be seen (p. 393) that the Pettman G.S. percussion fuze is specially designed to act only on direct impact. **Use.**

For the second purpose, it is necessary that the fuze should act on graze, and almost instantaneously, as otherwise the shell has time to rise to a considerable height before bursting, and thus its effect is diminished. Such an action is secured in the R.L. and B.L. plain percussion fuzes and in the sensitive fuze. This nature of fuze is absolutely necessary to develop the effect of segment shell when used against men exposed; with shrapnel good results have been obtained when using such a fuze at moderate ranges, but where the range is known, time fuzes are usually more effective. **On graze.**

Fuzes of this class are useful in firing trial shell to ascertain the range, as the effect of a burst on ground is easily seen.

Safety pins are used in the fuzes which act on graze, and serve to protect the "feathers" in the fuze which only come into use when the safety pin is withdrawn, guarding against risk while the shell is rammed home.

It is important to employ a detonating composition which keeps well; the earlier percussion fuzes frequently failed in this respect. Experience has proved that cap composition, properly pressed and varnished, resists climate well. **Keeping.**

All percussion fuzes in the service at present (except the B.L. plain, which fits inside the shell) are tapped with a screw thread to fit into the conical fuze hole of the shells. A fuze having its screwed portion conical can be screwed home much more rapidly than when it is of a cylindrical form, as the fuze will enter some distance into the conical fuze hole before the screw bites. There is no necessity for a shoulder, as a conical screw cannot be screwed too far home. **Conical screw.**

A great advantage of percussion fuzes is that they require no preparation, beyond withdrawing the safety pin in those fuzes which act on graze. The sensitive fuze is, however, an exception. **Advantages.**

It will be seen from the above remarks how important it is that there should be a fuze which can be used with shrapnel shell, so that they may burst on graze. At present this is not the case with heavy guns, as the Pettman G.S. is only designed for direct impact, and the use of the R.L. fuze is only allowed up to 64-pr. inclusive.

### *Pettman Percussion Fuze G.S., Mark II.*

See Plate, p. 386, and Drill Book, pp, 78, 81, and Plate at end. The Pettman fuze was intended for use with either rifled or **Pettman, G.S.**

S.B. shell, and accordingly was so arranged that it would explode in whatever direction it struck.

Disadvantages. This entails an arrangement which, though well adapted for the use for which it was designed, is unnecessarily complicated where end on collision only is to be considered, as is the case with rifled guns.

Another drawback to its efficiency is deterioration from damp, as it is impossible to protect the composition on the detonating ball by pressure and varnish in the same way as can be done in a cap. It was early found that the damp affected these fuzes, and they are now protected by luting the screw of the top plug with redlead moistened with shellac varnish, and coating the top with the luting.

Proof. It is specially designed so as to act on impact, not on graze; it will not explode on a shell passing through a wave, but will do so on striking a wooden ship.

It is proved as follows, fired from a 7-inch R.M.L. gun charge 22 lbs. over water, it should not burst on graze; fired from a 40-pr. B.L. gun with 4 lb. charge, at 200 yards range, it should explode on striking an oak butt or sand bags.

Description. The interior arrangements are as follows:—The bottom of the fuze is solid, having a fire escape hole in the centre, covered with a pasteboard disc; the top of the fuze is closed with a solid plug; immediately under this is placed a cylindrical one called the steady plug, exactly fitting the interior of the fuze; the centre of the upper part of this, and the lower part of the upper plug, are hollowed out to receive a small plain ball, which thus keeps the plugs a short distance apart. An annular groove (filled with detonating composition, and covered with very thin copper) is cut in the upper part of the steady plug, and three vertical fire escape holes are made through it.

A second plug, called the cone plug, also fitting the interior, is placed in the lower part of the fuze; the bottom of this is a hollow tube filled with mealed powder; two inclined fire holes, as well as a central one, pass from the top of the plug into the mealed powder tube; this plug is suspended by a wire passing through the tube. A hollow cup of lead, open at the bottom and resting on the suspending wire, surrounds the tube in the cone plug, and the upper edges of the cup fit into a recess in it. A metal ball having two projections in its vertical axis (the upper cylindrical and the lower conical) is placed between the steady and cone plugs, the projections resting in the central holes; this ball is roughened over, coated with detonating composition, and covered over first with fine gut, then with two thicknesses of thin silk, then enclosed in two thin hemi-

spherical copper cups, which again are covered by another layer of gut and three of silk. Each layer of silk and gut is varnished. The coverings are for the purpose of diminishing the sensibility of the detonating ball to the requisite point, and for preserving the composition from damp.

This fuze requires no preparation. All filled common shell with which this fuze is used are supplied fuzed, over the fuze is a coating of cement, and a wad also cemented down over it.

**Action.** On the explosion of the charge the wire suspending the cone plug is sheared; the lead cup is crushed up (the lower edges being forced into the undercut portion of the lower part of body of fuze); the tube of the cone plug is forced through the fire-escape hole in the bottom of the fuze, and kept in that position by the crushed lead cup; the steady plug also falls a distance, equal to the height of the lead cup before being crushed, towards the bottom of the fuze; the rotation of the shell disengages the large detonating ball from its supports, and it rests within the chamber of the fuze. On the shell striking a hard substance, the ball is thrown forward with great force, and the detonating composition, being brought violently into contact with the interior of the fuze, is exploded; and the flame passes downwards through the escape holes in the cone plug, ignites the mealed powder in the tube and the bursting charge of the shell. This is the action which would take place when fired from M.L.R. or S.B. guns, but in B.L.R. guns (with no windage), owing to the absence of any lateral motion of the shell in the bore, the disengagement of the large detonating ball from its supports cannot always be depended upon. It is to obviate this that the small plain ball and annular groove of detonating composition are placed on the upper part of the steady plug. On impact, the steady plug is driven with great force against the top plug, and the plain ball (which was thrown out of the cup on the explosion of the charge) is driven against the groove of detonating composition, causing it to explode, and the fire passes through the fire holes in the steady plug and cone plug, and ignites the bursting charge of the shell.

### *Fuze Percussion, delay action.*

**Delay action fuze.** For use in base of 64-pr. battering shell, see Plate, p. 394. The object of the delay action is to allow the shell to penetrate well into the masonry, &c. before bursting.

**Description.** This fuze consists of a body, slowing chamber, pellet, with detonator and guard.

Delay action fuze.

The body is of gun metal, with a hexagonal head to take the gas-check spanner, and tapped to screw into the shell and act as a gas-check plug. This head has the word "fuze" stamped on it so as to distinguish it from the ordinary gas-check plug.

It contains *the slowing chamber* made of gun metal and screwed into the body. This contains a central channel driven with ·8″ of composition, burning at the rate of 1″ in 9 seconds, at the top of this are two conical side holes opposite each other, and filled with F.G. powder. They connect the central channel with the outside, and are closed on the exterior with a band of paper shellaced on. There is also a little fine grain powder above the composition. At the bottom of the composition is a small pellet of mealed powder, and two pieces of quickmatch projecting slightly downwards.

Below the slowing chamber in the interior of the body is an air space to receive the gas, &c., resulting from the burning composition. Were it not for this air space the fuze would in all probability burst before the composition was nearly expended. At the bottom of the air space is screwed into the interior of the body a steel plug, pierced with four fire holes, and having a hollow needle projecting downwards. Immediately below the needle is a detonator containing cap composition.

This detonator occupies the upper portion of the gun-metal pellet, which is hexagonal in cross section at its lowest part, and slides easily (when free) in the interior of the body.

There is an under cut neck between the upper and lower portions of this pellet, into which dovetails the hexagonally shaped gun-metal guard, when the copper suspending wire is sheared on the shock of discharge.

Action.

On the shock of discharge the wire is sheared, the guard descends and dovetails into the recess in the pellet, so as to form one mass with it. On impact they fly forward the cap explodes against the needle, the flash passes through the needle and fire holes and ignites the quickmatch and mealed powder pellet. The composition is in turn ignited and burns till the F.G. powder is reached, when the flash passes through the side holes into the shell.

Caution.

As this fuze has no safety pin care must be taken in handling shells fitted with it.

## *R.L. and B.L. Plain.*

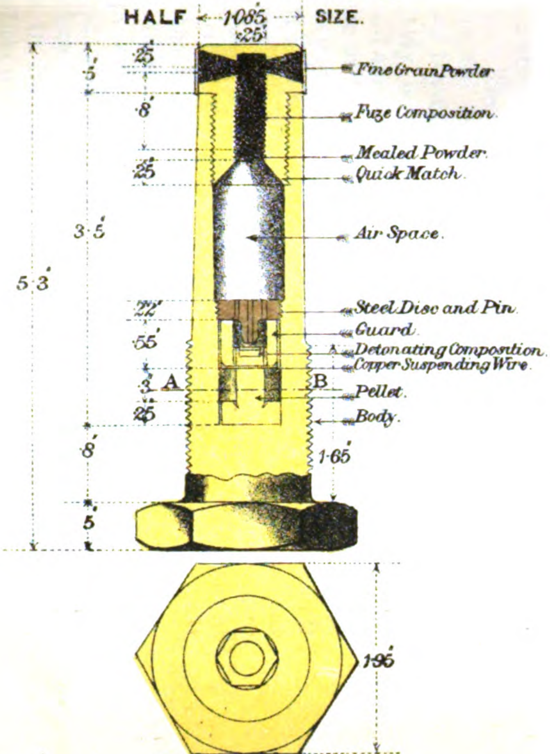
Fuzes to action graze.

The second class of fuzes will now be considered, namely those designed to act on graze.

To face page 394

## DELAY ACTION FUZE.

HALF SIZE.

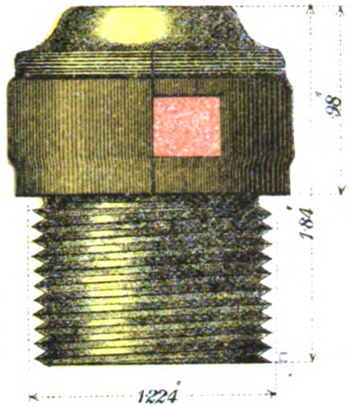



SECTION AT A.B.

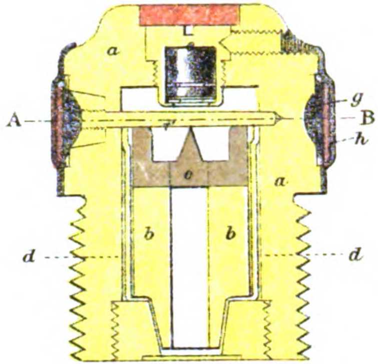
## SENSITIVE FUZE.

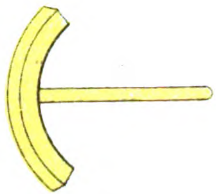
FULL SIZE.

ELEVATION.

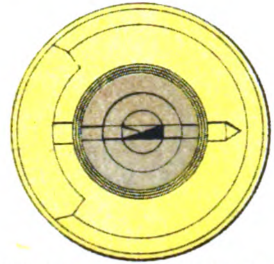



SECTION.



SAFETY PIN.



SECTION ON A.B. WITH PIN REMOVD.

DANGERFIELD LITH 22 BEDFORD ST COVENT GARDEN

This class has three representatives, viz. :— Fuzes to act on graze.

R.L. percussion.
B.L. plain.
Sensitive.

A short range is the most trying to these fuzes, as when the trajectory is flat the velocity of the shell is but little checked by grazing; they have, however, been found to act well at 400 yards, and even at shorter ranges. Our present experience is that these fuzes may be depended on over water and all natures of ground.

It was found that with a very small charge, such as the 4 oz. in 7-pr. gun, the R.L. fuze was not always set in action, and accordingly the sensitive fuze was designed to remedy this defect.

*R.L. Percussion, Mark II.*—See Plate, p. 386 and Drill Book, pp. 78 and 81 and Plate at end. This fuze will act either on graze or impact, and was introduced for use with light guns. R.L.

It is stronger than Mark I., which it otherwise much resembles. Marks.

Mark I. will continue to be issued for use with 7 and 9-pr. guns until the stock is exhausted, but should not be used with heavier guns.

Mark II. acts well with 64-pr. guns, and in the experiments against targets representing unarmoured ships was used with very good effect in the 9″ shell, fired with full charges (see pp. 255, 256). There seems no reason why it should not be used with shrapnel from heavy guns, but this is not at present authorised beyond the 64-pr.

The body is made of gun metal, screwed outside to G.S. gauge, and the top has a square hole for the G.S. key. Inside the centre of the head is a fixed needle, and the bottom is closed by a strong gun-metal disc, screwed into the body. There is a hole in the centre, covered by a thin brass disc. Description.

The working parts are—

The guard made of gun metal, and pierced with two holes through which the safety pin passes. It is recessed inside to receive the head of the pellet, and the top of this recess is slightly undercut, so that the pellet can expand into it.

The pellet is cast of equal parts of lead and tin, and has on the exterior two feathers or flanges on which the guard rests before the fuze is set in action: it is hollowed out, and receives in its top the copper cap, which is primed with cap composition pressed and varnished in the same way as in gun caps. The composition is further protected by a very thin disc

of brass; this has been found necessary to prevent premature explosions.

The safety pin is of double twisted wire; it passes through the head of the fuze and through the guard, and is kept in its place by the ends being opened out slightly, so as to bind in a conical cup, as shown in the plate. A thin disc of brass covers this cup, and the other end is closed by a lead pellet when the safety pin is withdrawn, see Plate, p. 386. The head of the safety pin is fitted with a loop of string. For preparation, see p. 81, Drill Book.

Action. When the safety pin is removed, the guard is supported by the feathers of the pellet. On the shock of discharge the guard sets back, shearing off the feathers, and the shoulder of the pellet is jammed into the undercut recess of the guard. On impact or graze the pellet and guard fly forward, and the cap comes against the needle and explodes. The flash passes down the centre channel, blows out the thin brass disc at the bottom and explodes the charge.

B.L. plain. *B.L. Plain Fuze Mark IV.*—See Plate, p. 388, and Drill Book, pp. 78, 81, and Plate at end. This fuze is used with 20-pr. segment shell.

Description. Its detonating arrangements are very similar to those of the R.L. fuze; but the fuze is weaker, the pellet is larger, and is driven with pressed mealed powder having a channel in the centre, while the cap is smaller and the central hole in the base is also driven with pressed mealed powder and pierced. In order to provide for its use with E. time fuze there are four fire holes in the top of the body, these are closed in the interior by a small washer of sheet brass. The body is of gun metal, and is cylindrical, with a rim at the top to ensure that it shall not be put into the shell the wrong way, which would cause premature explosion.

Action. Its action on impact is similar to the R.L.; should the time fuze act before impact the flash from it passes through the fire holes in the top and ignites the cap.

Sensitive fuze.

### *Sensitive Fuze, Mark I.*

See Plate, p. 394. This has been approved for use with 7-pr. R.M.L. guns, and 8″ and 6·3″ R.M.L. howitzers.

Although not at present a S.S. fuze, it is thought advisable to give a description as it would very probably be issued in case of war.

In general principle it resembles the German percussion fuze, p. 398.

It is designed so as to be equally efficient with very low charges and with the highest charges used in the above pieces.

The fuze consists of (*a*) body; (*b*) hammer or pellet; (*c*) steel needle; (*d*) thimble; (*e*) detonating cap; (*f*) safety pin; (*g*) outside primer of quickmatch, and (*h*) band. The body, hammer, and cap are made of gun metal, and so is the bottom plug, which has a fire-hole closed with a thin brass disc spun over. **Description.**

The hammer tapers slightly from top to bottom to allow it to move freely forward on impact of the shell. A thin steel plate, the centre portion of which forms the needle, is fitted as shown in the cut, into a slot in the top of the hammer, and a hole bored through the centre of the latter allows the flash from the detonator to pass on both sides of the steel plate and down into the shell.

The thimble is a thin brass cylinder, flanged at the bottom and encloses the hammer. It allows the latter to move freely forward, and going with it prevents the hammer from being impeded by dirt, &c., which might otherwise enter through the safety pin hole on graze or impact on earth, &c.

The detonating cap is screwed into the head of the fuze and secured by a small side "stop screw." It contains about 7½ grains of pressed mealed powder covered with a perforated copper disc. Below this is pressed 3½ grains of cap composition, which is covered with varnished fine white paper and a thin brass disc; the latter has a hole ·1″ in diameter in the centre to allow the needle to pass through to fire the composition.

The use of the meal powder is to ensure the production of a sufficient quantity of flame to communicate with the bursting charge.

The safety pin is of brass wire screwed to a heavy head of gun metal, as shown in the plate p. 394. It is secured by a strand of six-thread quickmatch, fastened by silk thread and coated with meal powder priming. The whole is covered with a tape and copper band, like that used with wood time fuzes, M.L. The safety pin fits easily through one wall of the body and into a recess in the opposite wall.

The fuze is "uncapped" by removing the tape and copper band. This is not to be done till the shell has been placed in the bore.

The flash of discharge burns up the quickmatch.* The **Action.**

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* Gun-cotton loosely twisted will in future be used in addition to the quickmatch, it is put round the head of the fuze after uncapping it.

Sensitive fuze. safety pin, now free to move, is whirled out by the centrifugal force due to the rotation of the shell. On impact or graze the hammer and thimble fly forward and the needle point enters the cap. The flash passes down the pellet, blows out the thin brass disc which closes the base of the bottom plug, and so fires the shell.

## OTHER TYPES OF FUZE.

German percussion fuze. *German Percussion Fuze.*—Plate, p. 398. A short description of this fuze is added. It is of a different type to any yet considered, and in the late trials by the United States Government it ranked first of the eight fuzes tried, which included the R.L. and the Pettman.

Description. The shell fitted for this fuze have a projecting shoulder D in the fuze hole, and on this, to keep the bursting charge in its place, a brass thimble H is put, resting on the shoulders D, D. It has fire holes in the bottom, over which a piece of cloth is pasted. In this thimble, and resting on its flange, is a metal plunger A, having a central fire hole B, and carrying it into the top a transverse metal bar P, having a projecting needle on its top side.

The fuze hole is closed by a metal cap F screwed in, this cap has in its centre a hole tapped with a screw.

There is a hole through one side of the head of the shell just above the plunger.

Action. This represents the shell as it is brought to the gun; the loader has a pouch, in which are kept the pin C and fulminate cap G.

At the instant of loading the pin C is put into the hole in the head, and retains the plunger in its place. The fulminate cap G is then screwed into the central hole in the cap, and the shell is loaded.

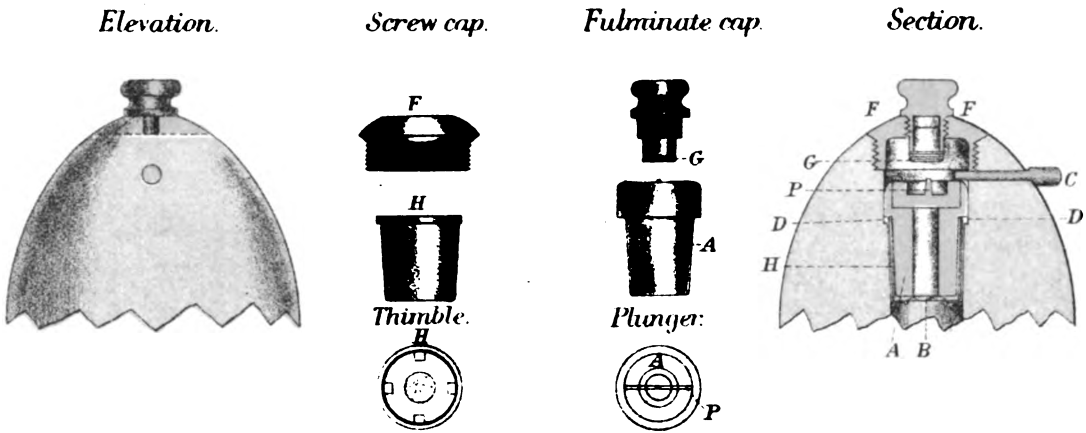
When fired the centrifugal force throws out the pin C, and on impact the plunger is thrown forward against the cap.

German time fuze. *German Time Fuze.*—Plate, p. 399. This fuze was ranked first among the time fuzes tried on the same occasion.

The fuze consists of the body in two parts A and B, and the igniter C.

Description. The lower part B is of lead and tin, and is cast round the brass stem *a*; the upper part of this stem is provided on the inside and outside with screw threads; into the inside is secured the igniter C; into the outer thread works the assembling ring *b*, which is prevented from turning when screwed down by the igniter; at the bottom of the stem is

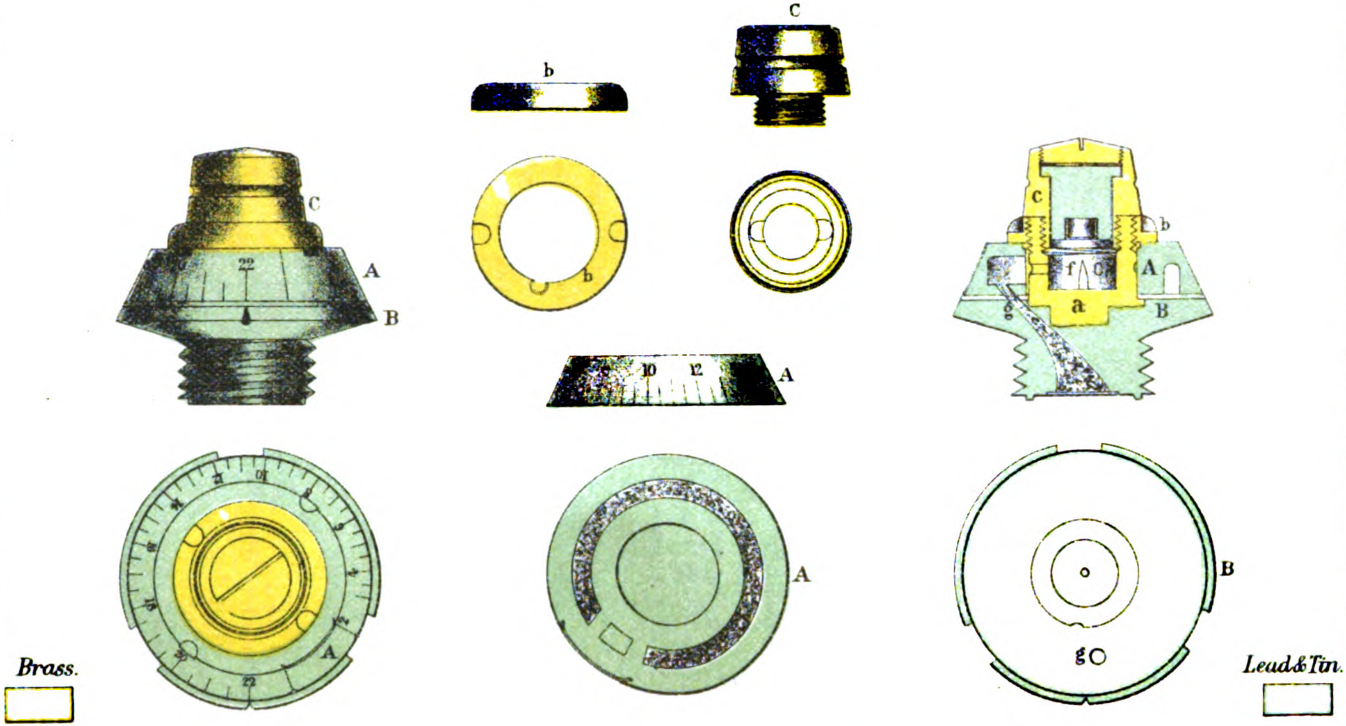
CERMAN PERCUSSION FUZE.




To face page 398.

Dangerfield. Lith. 22. Bedford St. Covent Garden.

# GERMAN TIME FUZE.




To face page 399.

Dangerfield Lith. 22 Bedford St Covent Garden

the needle $f$; round the exterior of the stem is a grooved channel, and through this are radial holes to allow the flash from the cap to pass into the priming chamber. German time fuze.

The upper part of the body or regulator A is a ring of truncated conical form; it has a priming chamber and a circular composition groove on its under side pressed with mealed powder. The rim of regulator is divided into spaces indicating each 50 metres, and is marked in even numbers from 2 to 22, each number representing hundreds of metres. Between A and B is a washer of felt. A channel $g$ through the lower part of B, filled with rifle powder, and closed by a thin disc, communicates the fire to bursting charge of the shell; the position of the upper end of this is marked on the rim of B by a triangular notch.

The igniter C needs no special description; the plunger is kept in its place by feathers at the top. These are sheared by the shock of discharge, and the flame from the cap passes through the radial holes in the stem into the priming chamber, and so to the composition.

The fuze is set by slacking C and $b$, and turning A until the required number of metres corresponds with the notch on the rim of B, then tightening $b$ and C.

## Blind Shell and Premature Bursts.

The chief causes of blind shells may be stated as follows:— Causes of blind shell.

1. From the time fuze not igniting. This would be likely to take place if a Mark I., M.L. fuze was used with a F.S. gun.

2. From the fuze being bored too long, and being extinguished on graze.

In this case the shell on striking the earth may shake out the fuze; the velocity of the shell being suddenly checked, the fuze has naturally a tendency to fly forward; if the practice is over water the fuze may be extinguished by striking the water. It is to be remarked that such a grazing action is very different to direct impact, which will generally make the fuze act, if it has powder channels; also that a metal fuze cannot fly out.

Blind shells are sometimes due to wood fuzes which have deteriorated by keeping, being bored in accordance with the range tables.

Suppose a fuze which should burn 10 seconds has increased its time of burning to 12 seconds, it is plain that allowance must be made by boring the fuze somewhat shorter than the

Causes of blind shell.

length laid down. If at practice shells are found to be blind, the first remedy to try is to shorten the length of the fuze.

3. From the hole not being bored through into the composition. This defect is peculiar to fuzes of the service pattern.

Too short a bit may cause a blind fuze, or the bit not being properly fixed in the hook borer. It is possible to bore so as not to pierce the fuze composition. This is very likely to happen when boring the 20-seconds fuzes with the hook borer, unless care is taken to keep the fuze in the proper position.

And with shrapnel in addition to the above:—

4. From the primer being covered with any foreign substance, for instance by rosin, which may have worked its way from the interior of the shell.

Premature bursts.

Shells sometimes burst prematurely, and this may occur after the shell has left the gun from defects in the fuze or errors in fitting, or while the shell is actually in the bore.

In the gun.

When a common shell bursts in the gun it is a most serious defect, as a shell with a large bursting charge exploding in the bore is nearly certain to disable the gun at least temporarily, and with the small number of heavy guns now carried by ships, might have a most important effect.

On the 30th May 1872, three 10″ shells burst on board H.M.S. "Hercules" when fired with a full charge of P. powder; the steel tube of one gun was cracked, and the bore of the others so scored as to require filing down before they could again be loaded.

Other instances of prematures have also occurred, and have generally caused defects in the gun.

Causes.

These were at first attributed to the fuze, and orders were given to discontinue the use of time fuzes, with all charges heavier than 14 lbs.; but experiments were carried out which showed that the same result was produced when filled shell were fired securely plugged, and the conclusions arrived at were:—

Premature explosions in the gun may be due to—

1. Defects in the shell and manner of filling.
2. Defects in fuze.

Defects in the shell.

1. Defects in the shell may arise from—

(*a.*) Rough lacquer or grit in the shell, and from no bag being used with heavy charges.

(*b.*) From the shell not being filled.

(*c.*) From a weak or defective shell.

(*a.*) This was formerly frequently the case, but latterly, owing to care in manufacture, an improved lacquer, and the

use with heavy guns of a serge bag for bursting charge, now rarely occurs. Defects in shell.

(b.) The great friction due to rotation and the setting back of the powder in an elongated rifled shell, render prematures from this cause probable, if a vacancy, however small, is left.

Under this head may be mentioned that a possible cause of prematures in small shell is their being filled so full that the time fuze cannot be properly fixed.

(c.) The Mark I. 10″ was proved to be very weak, and accordingly the new pattern is stronger, and it is believed that there is now no danger of prematures from this cause, except perhaps with shrapnel.

This latter case is not of so much importance, as the gun is not injured.

Defects in the fuze.

(2.) Prematures in the gun due to the fuze may arise from—

- (a.) A fuze not home (as when too large a bursting charge is used).
- (b.) A fuze which is too high in gauge, so as to throw the side holes above the bush.*
- (c.) A fuze without a paper lining where the wood has shrunk away from the composition.
- (d.) The powder channels coming high up, and not being sufficiently protected by the wood of the fuze when very heavy charges are fired; this defect has been remedied in Mark III. fuze.
- (e.) If a fuze be low in gauge it *may* set back so as to cover the fire-holes, and so cause a premature.

All these defects are peculiar to the service wood fuzes.

Premature bursts in the air.

Premature bursts in the air, as a rule, arise from error in boring the fuze.

In the above remarks time fuzes only have been considered. When using percussion fuzes, a premature or blind may of course be due to any of the causes before mentioned relating to defects in the shells or primers, but as a percussion fuze is firmly fixed in the shell, and no preparation is required,† except the removal of the safety pin, blinds or prematures caused by this fuze could only be due to defective manufacture, or to defects inherent in the fuze, unless it was used with a projectile for which it was not designed.

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* This seldom occurs with fuzes of the G.S. gauge.

† Except the sensitive fuze with low charges, *see* p. 397.

# CHAPTER XIX.

## GUN-COTTON AND DYNAMITE.

*See* Torpedo Manual, Vol. II., p. 144, and Treatise on Ammunition, p. 13.

The only explosives besides gunpowder which come within the scope of this work are :—

1. Gun-cotton.
2. Dynamite.

### Gun-Cotton.

*Properties and use.*

Gunnery uses. Experiments have been carried out with gun-cotton as the bursting charges of shells, and it may possibly be adopted for this purpose before long.

It is also used for priming for the sensitive fuzes, for which its easy ignition makes it very suitable.

All gun-cotton used in our service is now made at Waltham Abbey. A sketch of its manufacture will be found at p. 13 of Text Book on Ammunition.

The mean igniting point of gun-cotton may be taken at about 340°, but it may ignite at 277° F.

Form supplied in. For torpedo and mining services it is compressed when in the pulp state into discs or slabs of various forms. The usual form of disc is diam. $3\frac{1}{10}''$, length 2″, weight 9 oz.

As priming for fuzes it is made up in a loosely twisted strand.

Gun-cotton yarn, when steeped in saltpetre and covered with a coating of india-rubber, makes an excellent fuze; the combustion is rapid, about 30 feet per second.

Slabs are made $6\frac{1}{8}$ square and of three thicknesses, viz., $1\frac{3}{4}''$ weight $2\frac{1}{2}$ lbs., $1\frac{3}{8}''$ weight 2 lbs., $1\frac{1}{8}$ weight $1\frac{1}{2}$ lbs.

Ignition. When dry, gun-cotton, perfectly unconfined, is ignited by a flame, or by a heated body; it burns quietly and very rapidly with a bright yellow flame; if, however, the cotton is confined

in a strong case, even of wood, the action is very different, it explodes with great violence, and the strength of the explosion will depend upon the thickness of the case; to develop *it* fully a strong iron case is required.

**Detonation.** Compressed gun-cotton may be detonated, even when unconfined, by the action of various detonating bodies, of which fulminate of mercury is found the most suitable. It is this property that renders gun-cotton so valuable for torpedoes, destroying stockades, bridges, &c.

When about 5 grs. of fulminate of mercury are enclosed in a tin tube, and ignited in contact with a disc or slab of gun-cotton, a most violent action is set up; to guard against any chance of failure, 25 grs. are used. Various means are used for igniting the fulminate; a description of the service detonators will be found at p. 92, Treatise on Ammunition.

It is essential that the gun-cotton should be in a compact form, such as that produced by the pulping and subsequent pressing process, as light flocculent gun-cotton cannot be detonated by the fulminate.

The discs or slabs have one or more perforations in them to take the detonator or detonators.

The chief products of the explosion of gun-cotton are carbonic oxide, carbonic acid, water in the form of aqueous vapour, and nitrogen; the first is highly dangerous in confined spaces, such as mines, &c., as it is an active poison and very inflammable.

**Wet gun-cotton.** Gun-cotton is not injured by damp; when kept dry 2 per cent. is the usual amount of hygroscopic mixture found in it, and should this be increased by any extraordinary condition of the air, it again speedily parts with the excess of moisture, when the air returns to its former state of dryness.

It may be kept under water, and yet when dried again it will possess all its original qualities of easy ignition and susceptibility to detonation, so long as its mechanical cohesion be not destroyed. This will, however, be the case if it is kept immersed long, and not under pressure, as it will swell.

If this has occurred, by pressing it again to its original size it will recover its susceptibility to detonation.

If it is required to wet gun-cotton for safety it should be immersed for a quarter of an hour.

**Detonating wet gun-cotton.** Wet gun-cotton may be detonated by fulminate if a considerable quantity of the latter be used; or, as is the safest and most convenient plan in practice, by detonating a small quantity of dry gun-cotton in contact, or nearly so, with the

Detonating wet gun-cotton.

wet mass, by means of an ordinary detonator. One or two half-pound dry discs of gun-cotton, when thus detonated, will communicate their action to a large mass of wet gun-cotton. For instance, a charge of gun-cotton may be suspended in water, entirely unprotected from the latter, and detonated by means of a dry primer protected in a waterproof case. Wet gun-cotton is actually more powerful in its effects when detonated than dry.

Safety from fire.

At the same time, it is impossible to ignite wet gun-cotton by any flame. If a disc of wet gun-cotton be put in a fire it will gradually smoulder away as it dries, but no explosive effect will be produced.

These properties are most important. They allow the gun-cotton to be stored wet, in which condition it is absolutely safe from any danger of explosion by fire, and it can be redried at will for use in small quantities, or left wet for use in large charges, subject to the use of a dry primer as above mentioned.

Drying gun-cotton.

Wet gun-cotton may be dried by leaving it in the open air in dry weather exposed to the sun and wind. Even without sun it will dry in about five days. Of course the actual time taken to dry any given specimen will depend on climate, state of atmosphere, &c. If it be required to dry gun-cotton quickly, in ships where there is a drying room this may be used by heating the room, carefully putting out the fire and then hanging up the gun-cotton, taking care that it is not in contact with any metal.

Force of gun-cotton when detonated.

When gun-cotton is detonated, its action is so very rapid that no confinement is required, thus there ceases to be any necessity for using a strong case for torpedoes, or for tamping mines, and it can be used to cut down stockades, &c., by simply attaching the discs loosely to the obstacle.

The force of detonated gun-cotton is stated to be about four times that of exploded gunpowder, weight for weight, when used for submarine explosions, but in the open air may be taken to be much greater. It is, however, to be remarked, that to get this effect in the open air actual contact is necessary between the charge and the object to be demolished.

Masses of hard material, of great size or strength, such as blocks of hard rock, large iron castings, or thick bars of wrought-iron, may be broken up by simply placing upon one of their surfaces a comparatively small charge, quite unconfined, of compressed gun-cotton, or of a nitro-glycerine preparation, and exploding it by means of a detonating fuze. In such operations it is obvious that the destructive effect of

the detonation will be increased by covering the charge to be exploded by sand or other material, which will act as tamping; but, in hurried operations, results may be obtained with either of the materials specified, by detonating them when freely exposed to air, which could not have been produced by previously known modes of using explosive materials.

If it be required to disable an enemy's guns which cannot be removed, the following plan is given in the Manual of R.A. Exercises, 1879:— **Disabling guns.**

"Guns of 64-pr. calibre and upwards. Lash two 1 lb. slabs of dry gun-cotton together lengthways on the chase about 1 foot from the muzzle, having inserted a detonator with length of Bickford's fuze attached. It is then exploded.

"Should there be a projectile on the spot belonging to the gun it is desirable to see whether the bore has been so dented as to prevent loading, and if not to repeat the operation in the same place.

"If pressed for time it would be better with larger natures of guns to increase the charge so as to insure success the first time.

"50 yards may be considered in this case as a safe distance for the operators, and a 2-feet length of fuze burning about 40 to 50 seconds, this is long enough for safety.

"On all occasions of using Bickford's fuze with dry gun-cotton care should be taken that the tail of the fuze points to leeward, otherwise a spark may ignite the gun cotton before the fire reaches the detonator."

A heavy gun may be burst at the chase in a similar manner increasing the charge and placing it inside the bore, the latter being filled with water or sand if there is time.

When a gun is to be burst in this manner the distance for safety is much greater.

The demolition of stockades, bridges, and other structures, which it may be desirable to destroy or render useless as expeditiously as possible in the course of military operations, may also be effected with much greater ease, rapidity, and certainty by the aid of detonation than by the old method of operation; and the ease and safety with which compressed gun-cotton may be applied to these purposes has been demonstrated by numerous experiments.* **Demolitions.**

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* *See* Chapter on Fortification, p. 468.

Demolitions.

An illustration of the simple, rapid, and effectual manner in which the demolition of structures of great strength may be accomplished by the detonation of compressed gun-cotton, was furnished by the destruction of a martello tower at Rye; this tower was of circular form, built of brick, the wall 12 feet thick on the sea side, and tapering to 7 feet 6 inches on the land side; 200 lbs. of compressed gun-cotton were placed upon the basement in three piles freely exposed, which were ignited simultaneously; the demolition caused by the explosion was most complete, while not a brick was projected 50 yards from the spot. It was calculated that at least 1,200 lbs. of gunpowder must have been employed to produce similar results.

Comparative power of gun-cotton and powder.

Subsequent comparative experiments with gun-cotton and gunpowder have shown that a complete demolition of towers of these dimensions can be effected by means of 800 lbs. of gunpowder, fired by detonation, while not more than 150 lbs. of compressed gun-cotton, as now manufactured, would be required to produce the same result.

## *Safety of Gun-cotton.*

Safety.

Numerous experiments on a considerable scale have been made in order to test thoroughly the safety of compressed gun-cotton, the results of which show that, though not liable to explode when stored in small quantities, and under any circumstances much less dangerous than powder, it should, when stored *dry* in large quantities, be treated with the same precautions as gunpowder.

Report of committee.

The special committee on gun-cotton reported that "the "use of compressed gun-cotton (dry) is not only unattended "by either uncertainty or peril but that as an explosive agent "it is effective, certain, portable, and easy of employment"; and in 1874, in their final report, they point out that "gun-"cotton is not at all altered chemically by being kept in the "wet state, and does not appear to sustain any important "mechanical injury by long continued storage in the wet "condition." After pointing out that even a large fire will only cause wet gun-cotton to burn away slowly, they report that "a store of wet gun-cotton is perfectly safe under all "conditions of ordinary accidents, and that gun-cotton may "be carried in the wet state with perfect safety on board "ship."

It should however be noted that this safety depends on the care taken during manufacture to entirely eliminate all fatty and foreign matters from the cotton, and also to rid it of every trace of free or uncombined acid. Any trace of acid would be fatal to the keeping qualities of gun-cotton, and would make it dangerous, owing to its liability to decomposition and spontaneous combustion. **Effects of free acid.**

The litmus test given below is for the purpose of ascertaining whether any acid is present.

The following instructions for the preservation of wet and dry gun-cotton supplied to H.M. Ships, were issued 6th June and 19th August 1879. They specially refer to outrigger charges for torpedo purposes, supplied in hermetically sealed cases, but they apply equally to any other gun-cotton which may be supplied in cases for other purposes, such as field operations. **Care and preservation of gun-cotton.**

Gun-cotton discs and slabs are issued in wooden boxes, coated in the interior with crude paraffin, and those containing wet gun-cotton should be treated as to weighing, &c., according to paragraph 6.

Instructions specially relating to torpedo matters are omitted.

*Instructions for the management and preservation of wet and dry Gun-cotton (outrigger charges) supplied to Her Majesty's Ships.*

It having been decided to substitute hermetically sealed cases of damp gun-cotton with primers of dry gun-cotton for the iron 100-pr. outrigger cases now supplied, my Lords Commissioners of the Admiralty are pleased to direct that the following regulations with regard to their use, stowage, and preservation be observed:—

2. The same precautions are to be taken when embarking and disembarking gun-cotton, whether wet or dry, as are now directed to be taken with regard to gunpowder, and on all occasions when it may be necessary to remove the gunpowder from H.M. Ships, all gun-cotton, whether wet or dry, which is on board is to be removed also. **Embarking and disembarking.**

3. If there is sufficient room in the torpedo magazine, the gun-cotton, both wet and dry, is to be stowed there. **Where stowed.**

4. If there is not room for the whole, the dry primers should be stowed in the torpedo magazine, and the wet gun-cotton in the shell room.

5. If there is no torpedo magazine, the whole should be stowed in the shell room.

To be weighed. 6. The cases of damp gun-cotton are to be weighed during the first week of each quarter, to ascertain if they have lost any weight by evaporation. The weight of each case when first filled is marked upon it, and should the loss amount to 3 per cent. of what it was originally, the case must be opened, filled with water, the latter drained out again, and the case reclosed; its weight is then to be ascertained and marked upon the case, the former mark being obliterated.

Test for acids. 7. Ten per cent. of the dry primers supplied are to be examined the first week of each quarter, and tested by opening the case, moistening with a drop of fresh water one of the small pieces of blue litmus paper which are placed in the case for the purpose, and pressing it between two discs of gun-cotton, should the paper turn red, the contents of this charge must be soaked in water, and kept as wet gun-cotton: the test paper should not be touched with the finger when moistened, it should first be placed upon one of the faces of a disc, and the water then dropped upon it.

8. The surfaces of the discs, after being tested in this way, should be at once rubbed with some clean cotton waste to remove the small quantity of moisture, and the charge repacked. If, on opening the case, the litmus should be found to have already become reddened, the contents should be at once immersed in water and treated as wet gun-cotton.

9. The inspection of the dry primers should be carried out in as dry a place as possible.

10. Anything apparently unusual observed on inspection of the contents of a charge should be reported at once in addition to being noted in the half-yearly Report of Progress in Gunnery.

Detonators. 11. No detonators of any kind are to be kept in the same place as the gun-cotton, and after a charge has been fitted, the detonators must be removed before returning the charge to the magazine. No force is to be used for this purpose, and if they cannot be removed easily, the disc containing them should be thrown overboard.

Gun-cotton to be kept warm. 12. Gun-cotton charges when out of the magazine should always be under the charge of some responsible person.

In addition to the above instructions it should be noted that damp gun-cotton should be so stored that it shall not be exposed to a temperature as low as 32° F., as the freezing of the water might have the effect of disintegrating the gun-cotton and rendering it less susceptible to detonation.

## DYNAMITE.

Glycerine is obtained from oils and fats, both vegetable and animal, by treating them with alkali, which converts the fatty acids into soap, leaving the glycerine in solution. Nitro-glycerine.

Nitro-glycerine is prepared from glycerine by the addition of acids in a similar manner to gun-cotton.

It is a most powerful explosive compound of high specific gravity, and insoluble in water; in its pure and liquid state it may, with the adoption of special precautions, be handled with safety, but it has great tendency to undergo change, and a comparatively slight incentive may then cause its violent explosion.

Its instability and uncertainty render it unfitted for gunnery purposes in its liquid state.

*Dynamite* in its best form consists simply of a dry siliceous earth, saturated with liquid nitro-glycerine. There is decidedly less risk of accident in transporting dynamite than nitro-glycerine in the pure state, on account of the less liability to an escape of the substance from packages by accidental leakage, and because the effects of concussion are somewhat deadened by its mixture with an inert substance; and in the form in which it is now supplied, namely, that of slightly plastic rolls, which are produced by compressing the mixture, there appears comparatively little liability to separation of nitro-glycerine. It is as readily susceptible of explosion by means of a detonation as is nitro-glycerine; and though not so powerful an explosive agent as the latter its destructive powers are very greatly in excess of those of gunpowder. Dynamite.

Dynamite is manufactured by Messrs. Nobel, of Glasgow, and can be obtained from their agents in nearly all countries, as it is largely employed for blasting purposes.

It is of too uncertain a nature to be stored with safety on board ships, but on foreign stations if a supply of a powerful explosive were required for field or mining operations, it might happen that dynamite was the only suitable material procurable. Uncertainty.

Great care must be taken in its use and transport. It is usually supplied in paper boxes, and should any leakage be observed in a box, it should at once be made away with. Precautions in use.

It is not affected by damp, and can be fired under water, but should not be kept long under water without a waterproof covering, as moisture causes the nitro-glycerine to exude.

Precaution in use.

Charges which have been wetted must not be returned into store.

The readiness with which it freezes, viz., at 38° F., is a serious objection to its employment in service, as it then requires to be thawed before use by application of heat, which involves additional risk. This is best done by putting the dynamite in a tin case, and placing this in warm (*not hot*) water.

It should, however, be noted as a curious fact that in its frozen state it is much less susceptible to detonation than at other times.

# CHAPTER XX.

## MAGAZINES AND SHELL ROOMS.

The usual rule as to position of magazines is to have two magazines, one well forward and the other aft. **Position.**

This disposition is adopted in order to keep them away from the engines and boilers.

The number of shell rooms has hitherto been very limited, but the newer ships are now fitted with a larger number of small shell rooms, which plan much accelerates the supply.

### MAGAZINES.

**Magazines.**

Magazines in all iron ships are now constructed as water-tight iron tanks, lined with wood, the lining not being in contact with the iron. There is an apparatus by means of which they may be flooded, and it may be supposed that when full of water no small amount of fire outside could raise the temperature to such an extent as to endanger the powder, or to open the joints of the iron casing to such an extent as to allow the water to escape rapidly. **Construction.**

The powder, if the cases are properly closed, should not be injured by the admission of water to the magazine.

Every precaution must be taken to ensure the proper working of the arrangements for flooding the magazines, and the cocks should be occasionally turned, the water in the pipe being drawn off by means of buckets. **Flooding.**

Magazines are lighted from the outside, and the light given is usually quite sufficient for working the magazines in action; but if required to read labels, &c., some description of reflector must generally be used. **Lighting.**

In most ships ventilating machines are fitted; they are most important, and should be carefully attended to, and frequently tested. The uptakes also should be frequently examined, and should always be fitted with a grating over the mouth to prevent rags, &c., being stowed in them. **Ventilating.**

Magazine screens are only required round the magazine hatch, but in that place they should be carefully fitted and always kept down in action.

Stowage.

The stowage of powder in the magazines is arranged by the officers of the steam reserve and dockyard, and every bay is marked with a label showing the nature and number of cases which it should contain.

In armoured ships the battering charges should be those stowed nearest to the door, and at present the usual rule with unarmoured ships is to stow the full charges in a similar manner.

Spare powder of all descriptions should be stowed in that part of the magazine which is the most difficult to work.

The ready rack, containing two charges for each gun of that nature with which the gun is usually to be loaded when the bugle sounds "Action," should be in some convenient position, and the cases for manning and arming boats should also be easily reached.

The empty cases should be hung up in the handing room. The Queen's Regulations and Admiralty Instructions, *pp.* 281-284, contain full instructions as to working magazines, and the precautions to be taken in stowing them, &c.

In addition to these instructions, it is stated, p. 274, that—

Pebble powder.

He will take care that the Magazine, Shell, and Light Room Men are frequently exercised at their Stations; cartridge cases are on these occasions to be passed up, but for heavy guns only two charges of powder per gun (*i.e.* those already in the cartridge case) are to be passed up, as it is found that the practice of taking cartridges in and out of powder cases for practice wears out the cartridge bags from the friction of the large pebbles.

Magazine men. Exercising.

Exercising magazine men in ships whose charges are all composed of pebble powder is very difficult, as passing up wads or other light substitutes for cartridges is, owing to the great difference in weight, not of much use.

In these ships the only exercise for magazine men and powder men found to be of much practical use is to drill them at opening the magazine, repairing quickly to their stations, and passing up the first supply from the ready rack, repeating this as often as necessary.

It will be found that, unless notice has been given beforehand, the most usual cause of delay in getting this first supply arises from the deficiency of light, as the lamps take some little time to light and burn up.

Great attention should accordingly be paid to this detail; the men stationed should be instructed which lights are those required first, and should on no account be allowed to light them beforehand on general quarter mornings. **Magazine men.**

Where R.L.G. powder is carried, if the plan of passing up powder for exercise be followed, great precautions should be taken, and the captain of gun should be put in charge of his powder until it is all passed below.

In all cases of passing up powder the time should be taken from giving the order, and not from the arrival of the first charge, and warning should not be given beforehand, otherwise the value of the exercise is much impaired.

This remark also applies to the supply of projectiles.

In stationing men in a magazine, care must be taken that the most trustworthy men are placed in the magazine itself; they must also be strong where heavy charges are used. With charges of 70 lbs. and upwards it will generally be advantageous to work whips instead of passing up the cases by hand. **Stationing.**

Oiled rags, cotton waste, oakum, or cloths for cleaning, are not to be kept in magazines, or their passages.

The efficiency of the ventilation* of a magazine will depend upon the degree of dryness which the fresh air admitted into it possesses, and the rapidity of the current of dry air passing through it. **Ventilation.**

The dryness of air is indicated by the number of degrees by which its temperature exceeds its dew-point.

The common practice therefore by which magazines are opened for purposes of ventilation on fine warm days should be considerably modified, and the dew point of the air, as ascertained by the wet and dry bulb thermometers, should always be considered before using a windsail or other means of ventilation.

## Small-arm Magazine.

The same remarks as to stowage and ventilation apply to this magazine. **Small-arm magazine.**

There are frequently no artificial means of ventilation fitted, and it is sometimes very difficult to keep this magazin dry.

The cases required for arming boats must be kept in the most convenient place. These should also be used for passing

* P. 312, Text Book of Ammunition.

Small arm magazine.

up at quarters, and should all be marked for the boat they belong to, and for their position at quarters.

Officers' ammunition should be kept in this magazine or in the shell room.

## Shell Rooms.

Shell rooms.

Shell rooms, like magazines, are constructed as watertight iron tanks in most iron ships, and are also usually lined.

They are lighted like the magazines, and the same remarks as to lighting the lamps, stationing men, and stowage apply in this case.

In some ships it is the custom to keep a small number of shell ready slung on the floor of the lower handing room, on chocks fitted for the purpose, so that if required the supply may at once commence.

Taking heavy shell down from the racks, with the limited space in which the work must be done, is a work of time, and therefore a certain number should at once be got out of the racks on going to quarters. The description of projectile most likely to be required should be prepared for sending up, (*see* pp. 10 and 14).

Shell room party should frequently be exercised in providing the different descriptions of projectile for the broadside.

If boat's shell boxes and rockets be kept in the shell room they should be close at hand.

A box should be fitted as soon as possible after commissioning, containing a sufficient number of time fuzes, and of the required implements. This should be passed up at once on going to quarters, and taken charge of by the men stationed to fit fuzes.

# CHAPTER XXI.

## STOPPING LEAKS.

### General Remarks.

The only method which can be employed for quickly stopping the flow of water into a ship, in case the bottom is injured, consists in hauling some flexible covering over the hole outside.

The materials used for this purpose may be considered to belong to three classes :— **Materials used.**

1. The sails, awnings, or other canvas gear belonging to the ship.
2. Large thrummed mats, such as the service collision, or the Makaroff mat.
3. Small "shot hole stopper mats."

And the considerations which govern the choice of one of these kinds of leak stopper depend on the nature of the injury.

Shot-plugs are not considered here, as shot holes in an iron ship would probably be so irregular that a plug would be of little use. This was notably the case lately with the "Huascar."

Damages to the bottom may be classed under three principal heads :— **Damage to bottom.**

(*a.*) Small holes, such as shot holes; these may be readily dealt with by means of the shot hole stopper mats supplied, directions for the use of which are given below.

(*b.*) Large holes, such as break through both skins of our iron ships and admit water in very large quantities to the interior. Successful ram and torpedo attacks come under this head, and the only protection against them is internal water-tight sub-division, as it would be hopeless to attempt to stop the inflow of water by placing any external stopper over such a hole until the compartment was filled, and the inflow had

Damage to bottom.

consequently ceased. After this, however, the leak, if not too large, might be stopped by placing over it a sail or collision mat, and producing a pressure into the leak by pumping out the compartment.

(c.) Holes more serious than (a), but not so much so as (b), such as may be made by a glancing blow of a ram, an accidental collision, touching the shore, or by a partially successful torpedo attack.

It is in this case that collision mats or sails may be considered specially useful, and their utility depends on the rapidity with which they can be placed in position, and on their being correctly placed over the hole, so that by the pressure of water they may be sucked into it and stop the inflow.

Placing in position.

Different methods may be employed for the purpose of placing mats or sails in any desired part of the ship's bottom, and the particular manner of obtaining the best result will depend very much on the position of a leak, as the deep bilge keels generally employed in iron ships introduce complications which would not occur with a simple form of bottom.

The gear employed for placing a stopper in position consists of—

Whips.

1. Whips (or outrigger spars in the case of a mastless vessel) to get the stopper outboard.

   Some officers advocate keeping the collision mats rolled up neatly outside the ship, ready to be at once swept into position, whilst others consider that if kept outboard they would be more liable to injury from shot, and that a mat could be got into position in any given place quicker by carrying it to the place above where it may be required, and hoisting it out there.

Fore and after.

2. Fore and aft lines extending the whole length of the ship for placing and supporting the stopper horizontally.

Hauling down lines.

3. Hauling down lines under the bottom:

   These are of two kinds, viz. (a), the chains rove through holes in the bilge pieces (*see* Circular below), and extending over the most vital parts of the ship. Where these are in position, and the leak is within their range, they would generally be employed. If, however, the chains should not be rove, or the leak is below the upper bilge piece, or if it should be towards the extremities of the ship, (b) rope hauling lines must be used, being got under the bottom in the usual manner.

4. Lines for supporting the upper edge of stopper.

When preparing for action, the whips (and outriggers) should always be rove, the fore and aft lines got along outside, and two hauling down lines placed under the bottom forward, and the same aft. Preparing for action.

As regards the probable position of a leak, under ordinary circumstances of ramming, accidental collision, injury from shot or locomotive torpedoes, it would most likely be above the upper bilge keel, and bearing this in view, special appliances have been introduced over the most vital parts of a ship, by means of which a stopper can be easily and quickly applied. Position of leak.

On the other hand injury from touching the bottom, or from a submarine mine, would very likely occur below this upper bilge keel, or before or abaft the range of these special appliances. The following Circular, issued Jan. 27th 1877, contains instructions respecting these fittings.

## ADMIRALTY CIRCULARS.

*(Fittings for placing in position Service Collision Mats.)*

It being considered desirable that in ships having deep bilge keels provision should be made for placing in position the service collision mats lately ordered to be provided, I am commanded by my Lords Commissioners of the Admiralty to acquaint you that orders have been given to fit in all such ships hauling-down lines or chains which can be rove freely through holes cut in the webs of the bilge keels, and have their upper ends secured so that they may readily be made available for placing in position the mats referred to. Ships with deep bilge keels.

2. These hauling-down lines will be placed about 12 feet apart, over the length occupied by the engines and boilers, and passed under the keel from gunwale to gunwale.

3. The lines need not be kept permanently in place, and arrangements will be made for stowing them in convenient positions on board; but the commanding officers of ships thus fitted are to take care that these hauling-down lines are rove occasionally for practice. Lines not kept in place.

4. The commanding officers are also to take care that before going into action these lines are in place, ready for immediate use if required. To be ready action.

These orders have been modified by Circular of 3rd May 1879, as follows:—

*(Method of getting Collision Mats into position.)*

Captains to exercise discretion.

With reference to the directions contained in Admiralty Circular, No. 3, S., of 27th January 1877, my Lords Commissioners of the Admiralty, are pleased to direct that commanding officers of Her Majesty's ships are at liberty to employ whatever method may be found most efficient for getting the service collision mats into position.

*Shot Hole Stoppers for Iron Ships.*

Instructions issued in Circular 19th April 1873.

Small thrummed mats, made in accordance with patterns furnished to the dockyards, are to be supplied to every iron ship in the following proportion, viz. :—

| Vessels having Complement of | Proportion of Mats to be Supplied. |
|---|---|
| 400 and upwards - | 1 for every 35 of complement. |
| 200 to 400 - | 1 " 30 " |
| Less than 200 - | 1 " 20 " |

Instructions for getting into position.

The following instructions have been drawn up for the guidance of officers in getting the shot hole stopper into position :—

(*a*.) In placing the mat over the shot hole or leak, four lines are required; two of them to be passed under the bottom of the ship and secured to two beckets at the corners of the mat, the other two lines being made fast to the other two corner beckets for easing the mat down.

(*b*.) The mat to be then lowered over the side, and swept into position, care being taken to keep a steady strain on all lines.

(*c*.) The bowline as fitted is for checking the mat from being swept too rapidly by tide or too much headway.*

(*d*.) When the mat is over the leak, the small strop is to be hooked to one of the centre beckets in the mat; and a jigger hooked to the thimble and boused taut.

(*e*.) The short iron grapnel is to be used when a man cannot pass his hand through the hole.

* In this case a fore and aft line will be required.

## Collision Mats and Sails.

Instructions were issued in Admiralty Letter, of 10th June 1876 that collision mats were to be supplied or made in the proportion of two for every iron clad ship, and one for every other ship. Collision mats.

These mats are about 12 feet square, and consist of strong double canvas, thrummed, roped, and fitted with beckets.

The arrangements for getting them into position have already been stated. In some cases the experiment of rolling up the mat round a heavy bar at its lower edge has been tried, the mat being lowered to just above the hole, and then unrolled by the hauling down lines. This method answers well in the case of a plain hole, as the stiffness of the bar prevents the lower edge of the mat being drawn into the hole, but it seems probable that in most cases the edges of the hole in the bottom of an iron ship would be too jagged to carry out this plan successfully.

The experiments carried on in 1876, on board "Inconstant" with "Service" and "Makaroff" mats and sails led to the following conclusions— Inconstant experiments.

1. The "service" mat is handier and more useful than the Makaroff.
2. Best results were obtained by the use of unthrummed canvas, such as awnings, &c.

Successful experiments were also carried out in 1875 in H.M.S. Repulse, but it should be mentioned that the valve covered was not opened until the sail was in position over it. Repulse experiments.

A mizen topsail was used, doubled over a hawser, the double part being forward, so that in case of headway to the ship, the parts of the sail were pressed together. It was hauled down in the usual manner.

A mizen trysail was also tried single.

After a leak is temporarily stopped by any of the above plans, other means may be devised for making a more permanent protection, such as a plate or wooden shield put on from outside over the mat, and secured by screwing up to a cross bar inside.

In order to be able to ascertain quickly the exact position of a leak with reference to the waterline, it will be found a very good plan to place a number of distinctive marks along the ship's side on the upper deck, these marks corresponding to known positions below. By this means word can instantly be passed up from below as to the locality of a leak. Marks to show position of leak.

# CHAPTER XXII.*

## RETURNS, EXAMINATION, AND PRESERVATION OF GUNS, CARRIAGES, AND SLIDES.

### RETURNS AND EXAMINATION OF ORDNANCE.†

*Returns.*

Annual returns.

Officers commanding vessels of war of every description having guns on board, and likewise the Royal Marines, Royal Naval Reserve, and Coast Guard, having ordnance in their charge, are to furnish returns on 31st December, through the usual channels to the Admiralty for information and for transmission to the War Department.

W. O. form 1475 is to be used for S. B. guns, and form 1476 for rifled guns.

Marks.

It is necessary for the identification of guns that the descriptive marks should be accurately entered in the return.

The weight of the gun is marked on the top of the gun in front of the vent.

The initial of the factory‡ will be found on the left trunnion in all cases,§ and on rifled guns the numeral of pattern or mark is also on that trunnion.

The register number and years of proof§ will be found on the reinforce in S.B. cast iron guns, and on the left trunnion in the case of rifled ordnance.‖

Nature.

Under the head of "Nature," the proper name of the gun, with its nominal weight, is to be entered; as for instance, "32-pr. of 56 cwts.," "9-inch R.M.L. of 12 tons," "40-pr. R.B.L. of 35 cwt." The correct designation will be found in the memorandum supplied with each gun.

The column headed "Date of last examination" is to be filled in from the date of the last inspection, made by a qualified examiner.

Condition and sentence.

The "Condition of bore" and "Sentence" is to be taken from the last report made by a qualified examiner conducting the periodical or special examinations ordered; but if the gun has not been examined, owing to only a few rounds having been fired from it, these columns may be left blank, unless

* The contents of this chapter are still under consideration; it is therefore only provisionally printed. See Revised Instructions in Appendix, p. 507.

† See Art 812 Admiralty Instructions.

‡ With S.B. ordnance this would of course denote the foundry where the guns were cast.

§ On all guns proved since September 1857.

‖ Except in the 7-pr. R.M.L., where this information is found on the right trunnion.

the commanding officer should see cause to call special attention to the gun.

Number rounds fired.

The "Number of rounds fired" at the date of making the return is to be very carefully entered under the several headings; it is exceedingly important, for sake of the record, that the number should be given correctly. The number of rounds fired with projectiles since previous examination should also be given.

The number of rounds fired with projectiles at the time of making the annual returns is to be very carefully recorded from year to year. All the older cast iron guns which were in the service previous to records being kept, have had a number of rounds "assumed" from the size of the vent, in accordance with the instructions of previous circulars. The number of "assumed rounds" is to be entered every year in red ink, and the actual number of rounds in black ink. In the column in middle of return should be inserted the number of rounds fired with projectiles since last examination.

Vents, &c.

The columns regarding the condition of the fittings of the breech-loading guns, and the vents of muzzle-loading guns, will be filled in from the reports of the qualified examiner.

Defects.

Particulars of any special defect on the exterior or other part of the gun are to be noted in the column of "Remarks," if not entered in any other part of the return; as also any peculiar circumstance, such as the re-venting of a muzzle-loading gun, the bursting of a shell in the bore, the fracture of fittings, &c. Reference is to be made, when necessary, to explanatory documents.

Guns which have not been fired since the previous return are to be entered in the return; but the columns headed "Condition of bore," "Sentence," "No. of rounds fired," and condition of fittings, need not be filled in, the remark "Not used since 18 ," being entered against them.

Special return.

A special return is to be made when a gun is examined, whether provisionally or otherwise, after firing the prescribed number of rounds, or when a defect has been found in any particular gun, but in this case the word "Special" is to be substituted for "Annual" in the heading of the form. The annual return is to be sent as usual.

Impressions.

Impressions are not to be sent with the report unless there is any doubt as to the serviceability of the gun or guns; but should any gun appear to be in an unserviceable state, or to require re-venting or other repairs beyond what can be effected on the spot, impressions are to be forwarded with the report, for the information of the Director of Naval Ordnance.

Repairs or exchanges.

If guns be found unserviceable, or require re-venting or repair, they will at once be repaired or exchanged, if necessary, by requisition on the Commissary of Ordnance Stores, approved by the Senior Naval Officer.

A special report of the circumstances of such a case is to be made by the Senior Naval Officer to the Admiralty.

## *Examination.*

See Art. 813, Admiralty Instructions.

For this service any naval officer, who has been through a special training at Woolwich in the examination of guns and has received a certificate of competency as Examiner is to be considered a "qualified officer," in the same sense as the military officer appointed by the War Office to perform the duty.

Course to be taken by officers afloat.

Officers commanding Her Majesty's ships will from time to time, as the exigencies of the service permit, apply through the Senior Naval Officer to the Commissary of Ordnance Stores at the station, to cause their rifled guns to be examined, unless they themselves have at their disposal the services of a qualified officer. At Esquimault, as there is no Commissary of Ordnance Stores, application will be made to the head of the Naval Establishment for the services of the Engineer Officer, Royal Navy, specially qualified for examination and repair of guns. The Commissary, on receipt of such demand, will take the necessary steps to cause this service to be performed by the Inspector of Warlike Stores, if there be one, or otherwise by some competent person. On the completion of the examination, the result will be notified to the Commissary on W.O. Form 1476, and will be forwarded by him to the Senior Naval Officer for the information of the Officer Commanding the vessel, who will take such steps as he may deem necessary, under the orders of the Senior Naval Officer. In every case where guns are examined or repaired, a copy of the examiner's report, on W.O. Form 1476, will be left with the Officer Commanding, to aid him in the completion of his annual and special returns.

By other officers.

Officers in command of Royal Marine Artillery, Royal Marines, Her Majesty's Coast Guard, and Royal Naval Reserve, having guns on charge, will apply to the Commissary of Ordnance Stores to have such of their guns, as may require it, placed on the list for the next quarterly inspection by Royal Gun Factory examiners of the district in which the port they are stationed at may be situated. In case of emergency they will apply through the same channel for the

immediate services of examiners and artificers from the Royal Gun Factories. With regard to guns which have fired the prescribed number of rounds since examination, a notification of the circumstance is to be made on W.O. Form 1473, accompanied by gutta percha impressions, and practice from the gun will cease until its condition has been reported upon; the return on W.O. Form 1473 being sent through the proper channel to the Admiralty for information and for transmission to W.O.

**Periods.** With regard to the periods of examination the following rules are laid down:

All examinations other than those conducted by a qualified officer are to be considered as provisional.

Every gun must be examined either provisionally or by a qualified officer after firing a given number of rounds with projectiles as under:—

| | | |
|---|---|---|
| S.B. Cast-iron guns | Firing 10 lbs. charges and upward | 100 |
| | Under 10 lbs. charge | 200 |
| Rifled guns B.L. and M.L. | 9-inch guns and upwards | 50 |
| | 8″, 7″, and 64 prs. | 100 |
| | 40-prs. and under | 150 |

**Defects.** If there should be any appearance of fissures about the vent, or other defects likely to develop, all guns will be examined after every 50 rounds, or more frequently as the commanding officer may think fit. Under these circumstances with 10-inch guns and above, the commanding officer should have them examined after each quarterly practice.

**Accidents.** When any accident occurs, either at home or abroad, such as the bursting of a shell in the bore, the splitting of a breech-loading vent-piece, &c., immediate inquiry will be made into the circumstance, and the gun examined. If the Commanding Officer considers the damage to be of importance, he will send without delay a report of the circumstances through the same channel as his annual return, forwarding, if necessary for the illustration of his report, gutta percha impressions of the damage done to the gun.

**Discrimination.** Every officer in charge of guns should know how to examine provisionally the weapons with which he works, and should understand what defects in guns are serious and what defects may be disregarded, while it is of great importance that the examination of both guns and fittings should be very searching and exact, otherwise a small flaw left unnoticed may endanger the life of the gun in future.

**Condemnation, provisional.** In all cases where there are sufficiently serious defects, or if there be any doubt as to the serviceable state of the gun, it

must be provisionally condemned and a report made of the same as mentioned, p. 421.

Final.

Practice and experience are required in order to become a competent judge of the various conditions of all the different natures of guns in the service; and accordingly it is directed that final condemnation shall be pronounced only by the authorities of the Royal Gun Factories.

Examination after proof.

Every gun is carefully examined after proof and before being passed into the service, and in the case of R.B.L. guns with reference also to its breech fittings.

It is then marked with the broad arrow in front of the vent, and if it be a rifled gun a memorandum of examination is filled in, which is in fact a register sheet for that particular piece.

Memorandum of Examination.

The "Memorandum of Examination," W.O. Form 1340, of every rifled gun will be in possession of the officer in charge of that gun; and when a gun is returned into, or issued from store, this memorandum will accompany the transfer vouchers.* The number of rounds that have been fired will be accurately entered in the memorandum, which will be carefully preserved, as containing important information concerning the gun.

In it is given the information required by any one who has to examine a gun, viz., the material of the bore, and, in the case of muzzle-loading ordnance, a short description of the construction, with a woodcut showing the gun in section. The defects in the gun at the time of *its issue*,† the number of rounds it has fired, and the subsequent examinations are also stated.

## Method of Examination.

Examination. Details in instructions for armourer.

Officers in charge of guns will find in the Instructions for Armourers full details as to the methods of examining ordnance; the nature of defects which may be expected; directions as to sentencing guns; and instructions for the care and preservation of guns, carriages, and slides.

The following notes are given here for general information :—

Method of examination.

Guns are examined by means of a lamp, and should any defects be seen a sharp-pointed pricker or spring searcher is employed.

Impressions are also taken of the vent, and in the case of guns with coiled barrels of the powder-chamber and the base of the bore.

* See Art. 814, Admiralty Instructions.

† The position of defects developed on service are noted in a similiar manner.

Coiled wrought-iron barrels are liable to slight defects, caused by imperfections of manufacture; but these are as a rule not of much importance unless found to increase when the gun is used. **Defects.**

Their importance also depends much on their position, a defect in or near the powder-chamber being much more dangerous than if near the muzzle.

Steel barrels are free from these defects of manufacture, and in a new gun are generally perfectly smooth and even.

On the other hand any slight cracks are of much more importance in a steel than a coiled barrel.

Both coiled and steel barrels are in M.L. guns (especially where gas-checks are not used) liable to "Scoring" or "Guttering" about the seat of the projectile, caused by the rush of gas through the windage.

A shell bursting in the bore may split the tube, but generally the only result is to cut up and graze the bore more or less. This can usually be remedied on board, though it will as a rule disable the gun temporarily.

In sentencing a gun according to the state of the bore, it is essential to discriminate between defects which are characteristic of the material, and cannot wholly be avoided in manufacture, and those which are created or developed on service, such as cracks in a steel tube. In coiled barrels defects are often numerous and generally of little importance, while in steel barrels the case is reversed; defects seldom occur, but when they do they are generally speaking of great importance. **Sentence.**

Besides the bore of the gun it is necessary to examine the vent, the effect of service on which is seen either by a gradual increase to the channel of the vent itself, by an irregular wearing away of the bottom, by the metal of the vent setting up, and the gas forming a hollow ring round it, or by fissures or hair lines radiating into the metal of the bore from the edge of the vent bush. **Examination of vent.**

Should this ring be so deep or jagged and irregular as to be likely to retain a piece of cartridge, or if fissures appear in the copper, or should the latter be much worn, the gun would be condemned for rebushing. **Sentence.**

If the "hair lines" attain to any size, the gun must be provisionally condemned.

Armstrong B.L. fittings require much care, and should be frequently examined, and the faces of breech-screw and vent-piece tested with a straight-edge. **Armstrong B.L. fittings.**

The cross-head should not be loose, as instances have

Armstrong B.L. fittings.

occurred of its being broken off whilst firing. In all cases before taking a vent-piece into use for practice it will be advisable to test the soundness of the cross-head, as well as that of the neck, by tapping with a hammer.

In order to prevent serious damage to gun and vent-piece especial attention should be paid, both before and during practice, to the breech bush in the gun and the copper ring on the face of the vent-piece. If at all dented they should be carefully faced before use. During practice the officer in charge should ensure these points being looked to constantly, and stop practice with any gun or vent-piece in which eating away of the copper by the escape of gas begins to show itself. When this once sets up a few rounds are often sufficient to damage permanently the gun or vent-piece.

Examination of exterior.

Very considerable defects may exist on the exterior of a wrought-iron gun without the strength being affected.

Defective welds and flaws running round the gun are not uncommon, and are as a rule unimportant.

It also occasionally happens that on firing the outer coils shift. If this be found to be considerable the gun will be provisionally condemned; but a slight shift which does not increase may be disregarded.

If a shell should burst in the bore the exterior must be thoroughly cleaned and examined.

## Care and Preservation of Guns, Carriages, and Slides, &c.

Guns.

1. *Guns.*—See Admiralty Instructions, Arts. 808, 844, 845, 855, and 856.

The gas escape channels are always to be kept clear.

Sights.

2. *Sights.*—See Art. 828, Admiralty Instructions.

The sights themselves should be kept clean, free from grit and oiled; the exposed portions are bronzed if made of gun metal and blued if of steel, to preserve them from corrosion, and on no account are these parts to be burnished or cleaned in such a manner as to remove the bronzing or blueing more than it is of necessity worn off by fair wear.

Carriages and slides.

3. *Carriages and Slides.*—See Art. 808, 811, 845, Admiralty Instructions.

All nuts will be kept tightened up, and all bearings and parts of gear which work one upon another well lubricated and free from clotted oil and rust.

The carriage-rollers should revolve freely upon their axles, and only take a bearing on the slide when the eccentrics are thrown into gear.

When the rear rollers are brought into play for running up, and the pawls of the sockets placed, the latter should bear not on their pins but on their shoulders. **Carriages and slides.**

The faces of the buffer blocks upon the carriage and plat form should be parallel one to the other, or else the spindles of the buffers are liable to be twisted.

The friction roller of the elevating gear is liable to be set fast by corrosion, if so, it must be carefully removed and cleaned.

All bearings and frictional parts of gear must be kept properly oiled.

A carriage fitted with the hydraulic buffer will never be fired from unless it has clips, and before such a carriage can be dismounted from its platform the clips will be removed.

Hydraulic buffers must be carefully attended to, and any leakage remedied. If they contain too much or too little liquid they will not work satisfactorily.

During practice, the surfaces of the platform upon which the carriage slides will occasionally be slightly oiled to prevent seizure between the carriage and platform, and to ensure uniformity in the recoil. This is especially necessary in dry frosty weather and with the heavier guns.

Compressor plates and bars will on no account be oiled. A little superficial rust on them is not detrimental, but much rust is inconvenient, as for the same amount of compression by the levers, it varies the amount of recoil, in fact, the recoil may be one round very little and the next very great. If ars become so rusted they should be scraped.

4. *Projectiles.*—See Arts. 808, 847, Admiralty Instructions. **Projectiles.**

The studs are not to be polished with brick or other substance likely to wear them away. Projectiles are to be gauged at frequent intervals.

# CHAPTER XXIII.

## TRAINING MEN AND TARGET PRACTICE.

### Training Men.

*General Remarks.*

In newly commissioned ships.

The most essential point connected with gunnery, in a newly commissioned ship, is that the crew should be brought to work well together as soon as possible, each man getting a fair knowledge of, and being able to perform quickly and efficiently, the various duties belonging to the particular No. he holds at his own gun, and until this is effected it is advisable not to attempt individual training.

Clearing for action with silence and rapidity is one of the most important points, and until this is attained to the satisfaction of the captain the ship should be cleared for action every day.

After the men are fairly efficient in clearing for action and in the simple exercises, the daily drill might be discontinued, and at general quarters drill should be begun as it would be carried out in action, using voice tubes, &c.

It will generally be found inexpedient to devote much time at first to cutlass or rifle drill; all men may be assumed to have a fair knowledge of these drills before joining.

Regular system to be established.

As soon as possible after getting to sea a regular system of instruction should be commenced, omitting, however, all individual training for the first three months.

The quarters should be divided into divisions, and each division drilled once a week; on these occasions no one should be absent. One division should consist of men not stationed at the great guns.

The rifle companies should be divided into classes according to their proficiency and instructed separately.

The cutlass men should similarly be divided into squads for instruction.

The magazine and powder men should be exercised once a week in addition to general quarters.

Individual training.

When the crew are able to work well and steadily at general quarters, and have attained a fair general state of efficiency in the rifle and cutlass exercises, the attention of the gunnery officer should be directed to individual instruction.

Every working petty officer and seaman, not a seaman

gunner or trained man, should be put through the course of instruction for T.M., and those who attain the required standard of efficiency rated. **Trained men.**

Volunteers should be taken until they have all been through the course, and afterwards the remainder.

The trained men should be examined, and those who are efficient should be requalified, care being taken that this is noted on their certificates.

Any who are not found efficient must be put through the course, and if they then fail to requalify their qualification should be removed until their turn again comes for the training class, unless they prefer to continue the course in their watch below.

In large ships the quickest and best way of putting men through the required course is to form a class taken equally from both watches and in harbour to work them as day men, excusing them such duties as may be considered necessary. By this means they can be instructed more quickly and efficiently and the work of the ship suffers less in the long run.

If men after passing through the class are still very backward they should be drilled by themselves for one hour daily in their watch below.

**Ordinaries and boys.** Arrangements should be made for instructing ordinary seamen and boys, preparatory to passing for higher ratings. First-class seamen gunners are occasionally to be employed as instructors, not only for the purpose of assisting in instruction, but also in order that they may keep up the knowledge they have acquired in the gunnery ships.

Favourable opportunities are to be taken of landing the rifle companies and field guns' crews.

**S. G.'s and trained men.** Seamen gunners and trained men should only be drilled at general and at the divisional drills.

*Acting Seaman Gunner.*

**Men to be encouraged to qualify.** Petty officers and able seamen in seagoing ships who are likely to prove efficient captains of guns, are to be encouraged to qualify themselves under the instruction of the gunnery officer for the rating of acting seamen gunner.

See articles 341e and 773 Admiralty Instructions.

**Shooting qualification.** In addition to the qualifications there laid down they must have fired the following number of rounds at target practice, and must qualify themselves as 2nd class shots, performing their firing in a reasonable time.

1. Ten rounds from the gun used for short practice fired from the ship at a stationary target at ranges between 500 and 700 yards.

Shooting qualification.

2. Five rounds as above from the gun mounted in a boat, an opportunity being chosen so that the boat may have motion. In (1) and (2) points are to be given in the same manner as for heavy guns.

3. In ships where heavy rifled guns are mounted, 4 rounds of full charges, with (3 empty and 1 filled) shell from the gun of smallest calibre in the armament, not being less than 7-inch of 4½ tons. In vessels armed with light guns, 8 rounds of full charges with 6 empty shell or shot, and 2 filled shell. If possible half the above number of rounds are to be fired with the bearing and distance of the target altering, and the other half with the relative positions of the ship and target not varying. In both cases the range is to be between 1,000 and 1,500 yards.

For 1, 2, and 3, an average is required of—

8 for a 1st class shot.
6 „ 2nd „

They must also on going through the annual course of musketry qualify as 2nd class shots according to the directions laid down pp. 202 to 205 in the Manual of Rifle and Field Exercise for H.M. Fleet.

## Commander Drury's Aiming Target.

Use.

The aiming target should be frequently employed in individual drills; its use is to assist in training the gun's crews to fire quickly, and at the same time to enable the instructor to point out and correct the mistakes in aiming.

Description.

The target consists of a circular piece of iron 7-in. in diameter. It is in two parts which are joined by a hinge, and it is fixed in its place by being passed through the port and nutted on the outside.

In the centre of the target is a small hole ·2 of an inch in diameter, to admit the light, and the target is painted in rings of different colours and dimensions, namely:—

Bull's eye, ¾ in. diameter, red.—Centre, 1½ in. diameter, white.— Inner, 3 in. diameter, black.—Outer, 5 in. diameter, white.

The targets are always to be used in pairs; they are easily placed in position, and when finished with are to be stowed away.

Scoring.

The value of the shots is arranged to be as follows:

| | |
|---|---|
| Bull's eyes - - - - | 5 points. |
| Centre - - - - | 4 „ |
| Inner - - - - | 3 „ |
| Outer - - - - | 2 „ |

Practice.

It is intended that the target shall be chiefly used at sea where other objects are not obtainable.

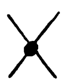
It is also to be used with the aiming drill given on p. 37 of the Gunnery Drill book; this drill is to be invariably carried out before prize firing takes place.

After a gun's crew have been sufficiently trained in the different methods of laying the gun, their efficiency is to be tested with the aiming target.

The result of the practice is to be entered in the following form and, after having been read to the gun's crew, is to be placed on the notice board for the Information of the ship's company.

*(Specimen Sheet.)*

AIMING PRACTICE. 9″ Gun. Date____________.

| Names. | Rate. | Position of shot. | Points. | Time. | Corrected Points. |
|---|---|---|---|---|---|
| | | | | ′ ″ | |
| William Jones - | A.B. |  | 4 | 1 35 | 3·75 |
| Michael Williams | Ord. |  | 0 | 1 45 | Lost. |
| John Brown - | C.M.T. |  | 5 | 2 15 | 2·75 |
| Michael Ahearn - | L.S. |  | 5 | 1 30 | 5 |

## REMARKS ON TARGET PRACTICE.

See Art. 794, Admiralty Instructions.

Object.

The object of target practice with great guns should be to train the officers and men in carrying out firing as nearly as possible under the same conditions as in action, and the allowance of ammunition should be made to go as far as possible in effecting this.

Circling round a target is never to be carried out, as by this means the bearing and distance of the object remains

nearly the same, and little is gained by practice under these circumstances.

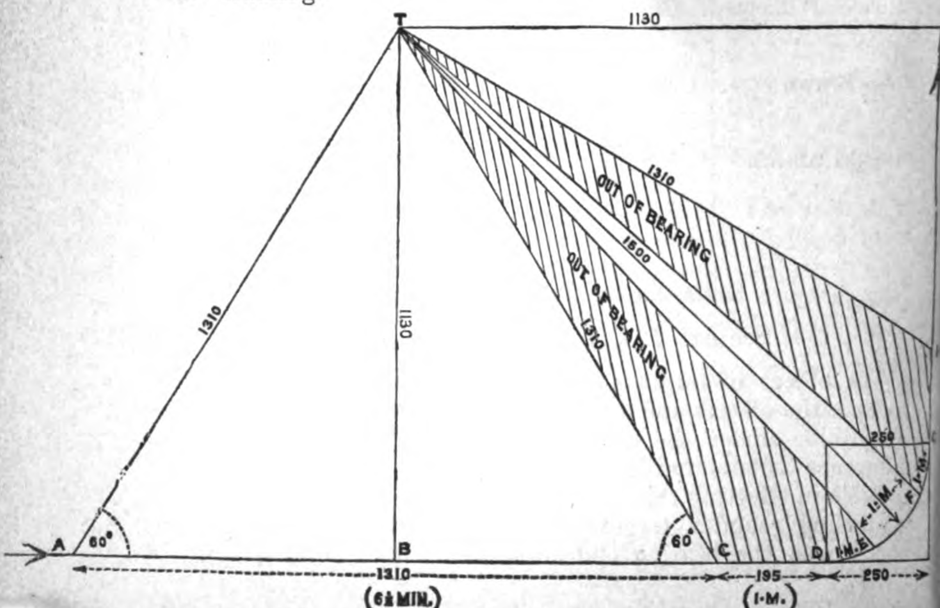
**Best way of manœuvring.**

The best way of manœuvring the ship so as to afford the most valuable exercise in the shortest time when firing at a target, is to make her travel round the target as nearly as possible on lines forming the four sides of a square.

The target first comes into view on the bow, and the distance and bearing alter regularly until it goes out of bearing on the quarter. The helm being then put over as the ship goes round the corner, the target comes into view again on the quarter, and changes its bearing rapidly with little or no change of distance until it again passes out of bearing on the bow. A course being now steered at right angles to the previous one the target again comes into view on the bow, and the same is repeated.

Under these circumstances, with the bearing and distance both continually changing, it will not be found of much use to fire at ranges over 1,500 yards. (*See* Chapter on Systems of Firing.)

To make this plan clear the following figure has been drawn for a ship steaming 6 knots and turning on an arc with radius of 250 yards, this being considered applicable to most ships. The distance from the arc of turning is taken at 1,500 yards, as being the maximum. The guns are supposed to have 30° training.



At a speed of 6 knots a ship will travel over a space of 200 yards in a minute. Best way of manœuvring.

Suppose the ship to travel along the line A, B, C, D, when she reaches A the guns will come into bearing at a range of 1,310 yards.

The distance will gradually decrease to 1,130 yards and then increase, the bearing altering all the time until an interval of 6½ minutes from A has elapsed, when the ship will reach C and the guns will no longer bear.

If she runs on for 1 minute to D and then turns, supposing the time for quarter circle to be 3 minutes, she will arrive at E in, say, 1 minute, and the guns will bear; at F 1 minute after they again will not bear, and in 2 minutes more she arrives at H, having completed one quarter of the square, when she again commences at A.

Thus from A to H the time is 11½ minutes, of which the guns bear for 7½.

Should it be desired to vary the distance more, the helm may be put over at C, and an oblong described instead of a square.

On every occasion of target practice with great guns, the machine guns should fire a portion of their allowance from the position where they could be mounted in action, and the top riflemen and marine small-arm men should also fire a few rounds, to accustom them to firing under these conditions. Machine guns and small arms.

Short practice should, as a rule, be carried out deliberately, the effect of each shot being pointed out to the class.

If hurried over, much of its value for purposes of instruction is lost. A record of points should be carefully kept, and inserted in the Gunnery Progress Book. Short practice.

The men to be instructed should be—

1. Men qualifying as T.M.
2. 3, 4, 5, 6, at guns, if not seamen gunners.
3. Leading men not stationed at guns.

Besides the above, any seaman gunners who are not good shots should be practised, as also any Nos. 1 and 2 at guns who may require practice.

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## ANNUAL PRIZE FIRING WITH GREAT GUNS.

The following system of competitive prize firing with rifled great guns is to be substituted for that now in force in Her Majesty's navy, after the 1st January 1881. Circulars cancelled.

And the following circulars, &c. are then to be considered as cancelled in all that relates to great guns:—

Circular No. 8 N. of 29th February 1872.
" 6 N. of 29th January 1874.
" 45 S. of 14th October 1875.
" 25 N. of 28th July 1877.
Ad. Letter N. of 11th October 1878.

The system is based upon the following points:—

Principles on which the system is based.

The great importance that not only should the Nos. 1 and 2 of the guns be good shots, but also that the men who in the event of casualties in action would have to replace them, should be able to do so efficiently; the manner in which the prizes are awarded, therefore, is made to depend upon the combined good firing of the six chief numbers of each gun's crew.

The prizes are awarded with regard to the combined accuracy and rapidity of the firing, and as the rapidity must to a very considerable extent depend upon the exertions of the whole gun's crew, the amount of the prize awarded to any gun's crew is divided and distributed in certain proportions to each man belonging to the gun.

The following regulations are to be strictly adhered to:—

When to take place.

(1.) The practice is to take place, if possible, not *later than* the third quarter of the year on the Home, Mediterranean, and North American stations, and than the second quarter on other stations.

Ammunition.

(2.) For the purpose of prize firing a special proportion of ammunition will be substituted for the ordinary quarterly allowance.

One nature of charge and projectile is to be used throughout the practice. Where supplied this is to be battering charge and Palliser projectile: guns unprovided with these to fire full charge and empty common shell.

Targets.

3. Targets of uniform size (detailed hereafter) are to be used throughout the service.

Speed.

4. Whilst carrying out this firing ships are to be steaming at a rate of not less than eight knots, and in the event of a ship not being able to attain this rate she is to proceed at her full speed.

5. In order to ensure that in all ships, as far as possible, the firing shall take place under similar conditions the following rules are to be observed:—

Distance.

(*a.*) The distance of the target is to be between 1,000 and 1,500 yards.

Course.

(*b.*) The ship is to steam round the target on the four sides of a square, as explained in the "Remarks on Target Practice."

(*c.*) The firing from any broadside gun is only to commence at the beginning of a side (A. in diagram, p. 432.), and is to be continued at the corner, and if necessary, on the next side, the gun's crew being at the "Still" when the gun does not bear.

(*d.*) The foremost and after guns in a central battery have frequently different arcs of training from the broadside guns; where this is the case, they are to fire from a broadside gun of the same nature, or, if there is none the conditions must be assimilated as much as possible. **Guns in angle ports.**

(*e.*) In vessels having guns of the same nature mounted both on the upper and main decks the prize firing is to take place from the guns mounted on the same deck. **Upper deck guns.**

(*f.*) Bow and stern gun's crews are to fire from a broadside gun, being completed, if necessary, to a full crew, and exercised beforehand. **Bow and stern guns.**

(*g.*) The distances are to be given to the gun's crew continuously, and as accurately as possible. **Range to be given.**

The firing is to be carried out from a broadside gun as follows:—

**Method of carrying out.** **How carried out.** The gun, loaded and run out, is to be extreme trained on the bow, and the crew closed up. The distance being named, the order "Commence" will be given as soon as the gun will bear, and eight rounds of rapid independent firing are to be delivered in the following manner, the change of numbers taking place immediately after the gun has been run out:— At the order "Commence," No. 1 will fire two rounds at the target, then change numbers with 2, who will also fire two rounds; after the fourth round 2 and 1 change numbers with 3 and 4, who each fire one round; and after the sixth round 4 and 3 change numbers with 5 and 6, who also fire one round each

**Turret ship.** In turret vessels, the captain of the turret will fire two rounds from each gun in succession; Nos. 1 and 2 will each fire two rounds, and 3 and 4 one round from the gun to which they belong.

An officer is to be stationed close to each gun whilst firing to take the time occupied from the order "Commence," until the eighth round has been fired.

**Gun out of action.** If during the firing a gun's crew is compelled to cease firing from the gun not bearing, or from any unavoidable cause beyond their control, the order "Still" is to be given, and the firing suspended until the officer superintending is satisfied

that it can be fairly renewed, when the order "Carry on" is to be given, the time during which the firing has been suspended being carefully noted and deducted from the total time occupied in completing the eight rounds.

The Nos. 1 and 2 of guns not firing should be on deck and exercised in judging distance.

**Compressors.** Great care is to be taken with regard to the proper adjustment of the compressors, and the security of the breeching, if used, especially when the practice is to be carried out with battering charges.

**Penalty for accidents.** Should accidents happen to the carriages or slides of a gun in prize firing from want of due attention, such neglect will render the gun's crew liable to the loss of any prize they may have gained.

**Prevention of accidents.** Should the officer superintending observe anything which endangers the safety of the crew, or the security of the gear, such as careless loading, gun left on the rollers, breeching not properly secured, &c., he is at once to cause the fault to be remedied, and the time occupied in so doing is to count in the total time taken in firing the eight rounds, unless it should be some defect beyond the control of the gun's crew.

**Measuring distance.** Two officers are to be stationed aloft with sextants, one is to continually observe and communicate the distance of the target, and the other is to take the distance from the ship of the point of striking the water of each shot.

**Registering practice.** A trustworthy man is to be stationed aloft to note the lateral distance from the target at which the shot fell, and this, together with the distance short or beyond deduced from the officer's observations, is to be inserted in the register of practice, Form A.

Points are to be awarded as follows:—

**Scale of points.** TABLE I.—Scale of Points to be awarded for Accuracy when competing for Prizes.

| Accuracy of Elevation. | | Accuracy of Direction. | |
|---|---|---|---|
| Distance over or short of Target. | Points. | Distance right or left of Target. | Points. |
| Hit direct - - - | 12 | — | — |
| From 5 yds. short to 50 yds. beyond - - - | 5 | 3 yds. to right or left - | 5 |
| From 15 yds. short to 60 yds. beyond - - - | 4 | From 3 yds. to 6 yds. right or left - - - | 4 |
| From 25 yds. short to 70 yds. beyond - - - | 3 | From 6 yds. to 10 yds. right or left - - - | 3 |
| From 35 yds. short to 80 yds. beyond - - - | 2 | From 10 yds. to 15 yds. right or left - - - | 2 |

A shot falling outside the limits of distance from the target named in Table I., with regard to accuracy, either of elevation or direction, is to be considered a lost shot, for which two points are to be deducted from the total.

A shot is only to be considered as a hit direct if it actually is seen to strike the target.

There is to be a fixed standard of time for each nature of gun. **Standard times.**

TABLE II.—Standard Times.

| Gun. | Standard Time. | Gun. | Standard Time. |
|---|---|---|---|
| | m. sec. | | m. sec. |
| 12·5-inch - - | — | 9-inch - - - | 7 40 |
| 12-inch, 35 ton - - | 13 15 | 8-inch - - - | 7 15 |
| ,, 25 ton - - | 12 15 | 7-inch - - - | 6 45 |
| 11-inch - - - | 10 5 | 64-pr. - - - | 6 45 |
| 10-inch - - - | 9 35 | | |

Points are to be deducted from the total number gained by each gun for any excess of time over this standard, in the following proportion:— **Deductions for excess of time.**

TABLE III.—Deductions for Excess of Time.

| Gun. | One Point to be deducted for every | Gun. | One Point to be deducted for every |
|---|---|---|---|
| | sec. | | sec. |
| 12·5-inch - - | — | 9-inch - - - | 7 |
| 12-inch, 35 ton - - | 13 | 8-inch - - - | 7 |
| ,, 25 ton - - | 12 | 7-inch - - - | 6 |
| 11-inch - - - | 10 | | |
| 10-inch - - - | 9 | 64-pr. - - - | 6 |

Prizes are to be awarded in accordance with the total number of points remaining to each gun after the above reductions have been made. **Prizes.**

There is to be no fixed minimum number of points required to entitle the ship to a prize; but the captain may withhold the prize if he thinks the practice unsatisfactory. **No minimum.**

In case of a tie the quickest gun is to be awarded the prize.

At the termination of the whole of the competitive firing in each ship, the gunnery lieutenant (or, if none on board, an officer selected) will furnish the captain with a detailed report of the result, in accordance with Form C., and the prizes which are allowed to the ship, in accordance with Table IV. annexed, are to be paid by the paymaster (on the captain's order) to the gun's crew, or crews, to which prizes have been awarded, as soon after as is convenient.

## Returns of Firing with Great Guns.

The following forms are to be used, and will be supplied, on demand, in the usual manner from the stationery offices in the Dockyard.

Form A. *Register of great gun practice.*—This is to be used for recording the shooting.

Form B. *Result of target practice.*—From the registers of great gun practice a table of this form is to be prepared showing the rounds fired, and points gained by each man; after submission to the Captain, this should be put up in some convenient place for the information of the ship's company, and afterwards preserved for record.

Form C. *Return of target practice.*—This return is to be prepared in all vessels from which target practice takes place, and is to be forwarded by the first opportunity after the practice to the Commander-in-Chief or Senior officer, who in the case of prize firing will transmit it to the Admiralty with as little delay as possible.

From D. *Squadron return.*—A return of this form is to be promulgated in each squadron as soon as the returns of prize firing have been received.

It is to be prepared by the Gunnery Lieutenant (if none on board by a Lieutenant) of the Senior Officer's ship.

A copy is to be transmitted to the Admiralty.

# FORM A.

## REGISTER OF GREAT GUN PRACTICE.

*Date* *Kept by*

| No. of Round (1) | Result (2) | Gun (3) | Name of Man who fired (4) | No. of Round (1) | Result (2) | Gun (3) | Name of Man who fired (4) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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*When used by the Officer or Man judging the practice Columns 1 & 2 are to be filled up, and when used in the Battery, Columns 1 & 3 during the firing & Column 4 afterwards.*

H.M.S.
Date.

# FORM B.

## RESULT OF TARGET PRACTICE.

*In the case of filled Projectiles the approximate distance from the Target at which the Shell burst. to be inserted and write "Shell." With case Shot insert the word "case" with no distance*

| Nº of Gun | Nature | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | | 6 | | | 7 | | | 8 | | | Total Points for Gun | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Name of Firer | Result | Points | Name of Firer | Result | Points | Name of Firer. | Result | Points | Name of Firer | Result | Points | Name of Firer | Result | Points | Name of Firer | Result | Points | Name of Firer | Result | Points | Name of Firer | Result | Points | | |
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Remarks as to General Nature of Practice

Gunnery Officer

Approved

Captain

To face page 438.

To face page 438.

H.M.S.

# FORM C.

## RETURN OF TARGET PRACTICE FOR QUARTER ENDING

Date. State of Weather Motion of Ship Speed of Ship

| Nº of Gun | Nature | Number at the gun of Men who fired Marines in red | Distance of Target | Independent Firing omit exceptional projectiles | | | Broadside Firing | | | Exceptional Projectiles Nature and Number | If Prize Firing | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Gun directing | | Electric | | Time | | | Points to be deducted for excess of time | Total Corrected Points | Prize | State opposite each Gun, whether it fired quickly and its general efficiency |
| | | | | Nº of Rounds | Total Points | Average | Nº of Rounds | General Result | Nº of Rounds | | Standard | Actual | Excess | | | | |
| | | | | | | | | | | | | | | | | | |
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Gunnery Officer

Note: This return is to be sent to the Commander in Chief as soon as possible after the completion of each Quarterly Target Practice. The guns are to be arranged in order of Merit for independent Firing. Any General Remarks on the whole practice may be inserted below.

Approved.

Captain.

Dangerfield Lith 22 Bedford St Covent Garden

# FORM D.

______________ SQUADRON

## ANNUAL COMPETITIVE PRIZE FIRING WITH GREAT GUNS FOR THE YEAR.

| Ships in Order of Merit | No. of Guns Competing | Date of Practice | Weather and force of Wind | Ship | | Average for each nature of Gun | | | | | | | | Average corrected points for all Guns | Best Gun | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Motion | Speed | Nature | Number | Time | | | Points | | | | Nature | Time | | Points | | Order of merit of best Guns | |
| | | | | | Knots | | | Standard | Actual | Excess | Actual | Deducted | Corrected | | | Standard | Actual | Actual | Corrected | | |
| | | | | | | | | | | | | | | | | | | | | | |
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Approved ______________ { Commander in Chief or Senior Officer.

## TABLE IV.

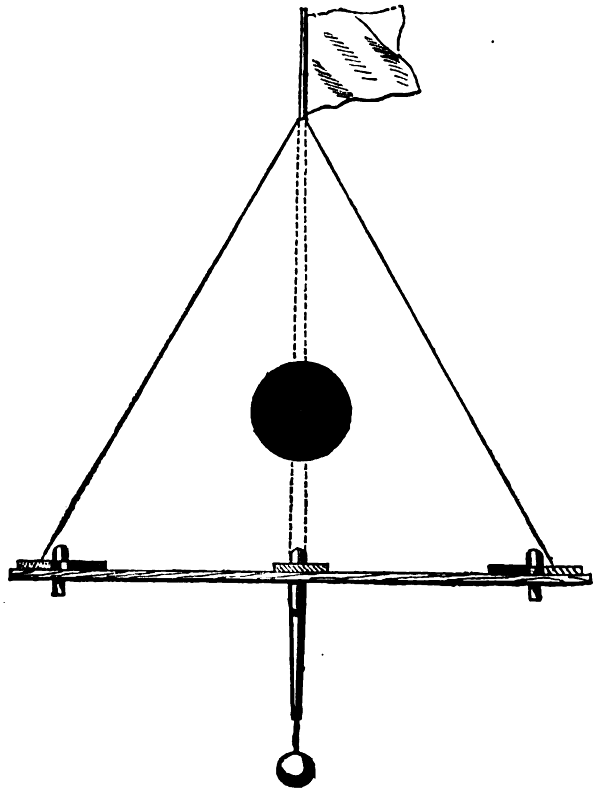
### Scale of Prizes awarded annually to Sea-going and First Reserve Ships in proportion to their Armaments of Rifled Guns.

| Armament. | Annual Prizes allowed in proportion to Armament. Total Number. | Class of Prize. | Proportional Amount awarded to each Man of Gun's Crew. No. 1. | No. 2. | Nos. 3, 4, 5, and 6, each | Remainder of Gun's Crew, each | REMARKS. |
|---|---|---|---|---|---|---|---|
| **SEA-GOING SHIPS IN COMMISSION.** | | | | | | | |
| | | | £ s. d. | £ s. d. | £ s. d. | £ s. d. | |
| 18 heavy rifled guns, and above that number. | 3 | 1st | 2 10 0 | 1 5 0 | 0 10 0 | 0 5 0 | Rifled guns of 4½ tons and upwards are called heavy guns, and of less weight light guns. |
| | | 2nd | 1 10 0 | 0 15 0 | 0 7 6 | 0 4 0 | In vessels having a mixed armament of heavy and light rifled guns, each light revolving gun is to be considered, with regard to the prizes allowed, as a heavy gun, because it is worked by a full gun's crew. |
| | | 3rd | 0 16 0 | 0 8 0 | 0 4 0 | 0 2 6 | |
| Under 18 heavy rifled guns, and not less than 10. | 2 | 1st | 2 0 0 | 1 0 0 | 0 8 0 | 0 4 6 | Each pair of light broadside rifled guns are to be considered, with regard to the prizes allowed, as only one heavy gun (having only one full crew to work both guns). |
| | | 2nd | 1 0 0 | 0 10 0 | 0 6 0 | 9 3 0 | |
| Under 10 heavy rifled guns, and not less than 4, except turret ships mounting guns of 10-inch or higher calibre. | 1 | - - | 1 10 0 | 0 15 0 | 0 7 6 | 0 4 0 | In turret vessels carrying 4 guns of 10-inch or higher calibre a prize will be awarded as follows:—<br>£ s. d.<br>Captain of the turret - - - 2 0 0<br>Nos. 1 and 2 - - - - 1 0 0 each.<br>" 3 and 4 - - - - 0 8 0 "<br>The rest of the guns' crew stationed inside the turret, at the running in and out winches, and employed in hoisting the projectiles into the turret. } 0 4 0 each. |
| **FIRST RESERVE SHIPS IN COMMISSION.** | | | | | | | |
| 10 heavy rifled guns, and over that number. | 2 | 1st | 2 0 0 | 1 0 0 | 0 8 6 | 0 4 6 | |
| | | 2nd | 1 0 0 | 0 10 0 | 0 6 0 | 0 3 0 | |
| Under 10 heavy rifled guns, and not less than 4. | 1 | - - | 1 10 0 | 0 15 0 | 0 7 6 | 0 4 0 | |

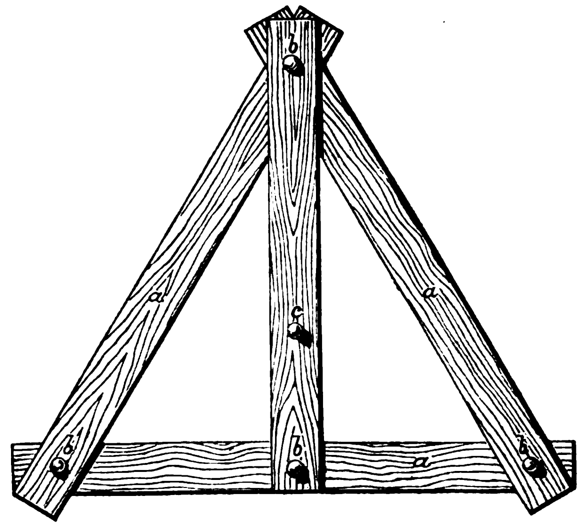
*Note.*—If the turret is trained by hand-power during the competitive prize firing, the men actually working the training winches of the turret in which the gun which wins the prize is mounted, are each to receive 4*s.*

## SKETCH OF TARGET TO BE USED FOR PRIZE FIRING.

ELEVATION.



PLAN.




*a a* are planks 12 feet in length by 1 in width, forming a triangular platform and connected with wooden pins *b b*, *c* is a hole through which passes an upright staff of about 15 feet in length, 3 feet of which are under water, and to the lower end is attached a shot; at about 18 inches from the top of the centre staff three small ropes are taken to the corners of the triangular platform, and secured taut; outside these ropes, and attached at the apex to the centre staff, is a triangular-shaped canvas screen, having a black bulls eye 2 feet in diameter. A small flag is placed on the top of staff.

Each ship will in future be supplied with the necessary materials for repairing such targets.

# Electric Firing.

## *Electric Firing Gear.*

The following regulations to be observed in ships fitted with electric firing gear, extracted from Circular No. 2 S., 10th February 1880, are inserted for the convenience of Officers:— Firing gear. Regulations.

In each vessel fitted with electric firing gear at least two of the Commissioned Officers of the military branch, one of whom is to be a Lieutenant, are to be thoroughly instructed in its use, and to be competent to carry out electric firing from the director.

The names of the officers are to be inserted in the half-yearly reports of progress in gunnery and torpedo practice.

The electric firing wires are frequently to be tested by the Gunnery or Torpedo Officer, where one is borne, and always, if possible, before general exercise.

Two armourers or artificers are to be specially instructed in the manner of repairing the wires when damaged, and are to be stationed in the battery at general quarters for this duty.

A small box is fitted upon each side of the battery for the use of these men, and is to contain short pieces of india-rubber tubing, india-rubber tape and solution, binding screws, pliers, twine, short lengths of insulated wire fitted with binding screws and tubing for bridging over temporarily a break in the main wires, spare branch wires complete, and at general quarters spare boxes of electric gun tubes.

## *Electric Firing.*

In order that the fullest advantage may be taken of the method of firing broadsides by electricity, and that the conditions under which it is used in practice may be assimilated as much as possible to those likely to occur in action, the following orders are to be carried out:— Firing.

(1.) In all ships fitted with electric firing apparatus the guns are to be fired at a target by electricity, every quarter except that in which competitive prize firing is carried out. Period.

(2.) (*a.*) One broadside is to be fired from each side, the firing being carried out from the director; and, in addition, Amount.

(*b.*) Each of the Officers mentioned above as being competent to carry out electric firing from the director is to fire

at least two rounds from single guns in the same manner as a broadside.

Charge and Projectile.

(3.) Battering charges are to be used in all ships where they are supplied.

Palliser shot or empty shell are to be used if supplied; if not, empty common shell.

Method of carrying out by director.

(4.) Electric firing from the director is to be carried out in the following manner:—

The guns being concentrated on any bearing, the ship is to be manœuvred under steam at a speed of not less than eight knots, so as to pass the target, the course being occasionally altered, so as to imitate the probable circumstances of a real engagement, but the Officer at the director being informed of any such change.

The Officer stationed to ascertain the distance of the target is to keep the Officer at the director informed of it.

The latter should endeavour to deliver the first broadside as soon as it would be effective; this would, as a rule, be within 800 yards (see Chapter on Systems of Firing); the subsequent broadsides or single shots should be fired on the same or different bearings as the captain may direct; if necessary the helm being used to bring the sights on.

No attempt should be made to pass the target at the exact distance for which the guns are concentrated.

Recording results.

(5.) Whenever electric firing is carried out, Officers with sextants should be stationed aloft as in prize firing, one of these should record the exact distance of the target at the moment of firing, and another the distance from the ship at which the shot fell.

The distance, right or left of the target, at which the shot struck should also be estimated and recorded.

In the case of broadside firing these distances should be taken from the spot where the bulk of the broadside fell, and the lateral and longitudinal spread should also be estimated.

These distances, if compared with the curve of the trajectory, will give the number of shot which would have struck the side of a ship in the same position as the target.

Report of firing.

(6.) A full report of these firings is to be inserted in the half-yearly report of progress in gunnery, the following points being specially recorded:

(*a.*) Bearing and distance for which guns were laid.

(*b.*) Actual distance of the ship from the target when the fire was delivered. Report of firing.

(*c.*) Distance from the target, right, left, short, or over, at which the shot struck the water.

(*d.*) In the case of broadside firing, the area covered by the shot.

(*e.*) Motion of ship at the time of firing.

(*f.*) Speed of ship at the time of firing.

(*g.*) Name of the Officer who fired.

(*h.*) A full report of the number of electric gun tubes and drill tubes fired during the half year, with the number of missfires, together with any defects discovered in the electric apparatus for firing the guns, is also to be made in the half-yearly report of torpedo practice.

## Ammunition Allowed for Practice Quarterly. (1.)

| Charges. For Armament. Proportion. | Charges. For Armament. Battering. | Charges. For Armament. Full. | Charges. For Armament. Reduced for Blank firing and Night Quarters. | Charges. Boat or Field Guns. | Charges. Short Practice. 4 | Projectiles. For Armament. Allowance for each Revolving Gun, each Broadside Gun of 4½ tons and above, and for each pair of Broadside Guns under this weight. 2 — Nature of Gun. | Shell Common. Filled. | Shell Common. Empty. | Shot. 6 | Exceptional Projectiles. See Note 5. Shell, Filled. Double. | Shell, Filled. Shrapnel. | Shell, Filled. Segment. | Case. | Boat or Field Guns. For each Gun. M.L. 3 | Boat or Field Guns. For each Gun. B.L. | Fuzes. | Rockets, War. 7 | Machine Guns. Nordenfelt. 8 | Machine Guns. ·65 Gatling. | Machine Guns. ·45 Gatling. 9 | Small Arms. Rifle. 10 | Small Arms. Pistol. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| For each Revolving Gun, each Broadside Gun of 4½ tons and above, and for each pair of Guns under this weight. 2 | 2 | 6<br>If no Battering charges, 8 full. | 2<br>If no Reduced charges, full in lieu. | 8 charges for each. 3 | 20 charges and projectiles for every 100 and fraction of 100 in the Complement, to be fired from the lightest Gun on board. | Rifled Guns: 8-inch and larger calibres. | 1 | 4 | 3 | — | 1 | — | 1 | 2 Common shell filled.<br>4 " empty.<br>1 Shrapnel " filled.<br>1 Case shot. | 2 Segment Shell filled.<br>2 " empty.<br>3 Shot or Shell empty.<br>1 Case. | Time or Percussion may be used. | One for each Rocket Machine. | 60 rounds for each Gun. | 200 rounds for each Gun. | 480 rounds for each Gun. | 20 rounds ball and 5 rounds blank for each Marine's Rifle. 25 rounds ball and 5 rounds blank for each Seaman's Rifle. | 15 rounds for each Pistol. |
| | | | | | | Rifled Guns: 7-inch | 1 | 3 | 4 | 1 | 1 | — | 1 | | | | | | | | | |
| | | | | | | Rifled Guns: 64-pr. | 1 | 7 | — | — | 1 | — | 1 | | | | | | | | | |
| | | | | | | Rifled Guns: B.L., 40 or 20-pr. if armament. | 1 | 7 | — | — | — | 1 | 1 | | | | | | | | | |
| | | | | | | Special for guns mounted on U.D. of Ironclads: | | | | | | | | | | | | | | | | |
| | | | | | | B.L., 20-pr. | 1 | 3 | — | — | — | 2 | 2 | | | | | | | | | |
| | | | | | | S.B., 24-pr. | — | — | — | — | — | — | 4 | | | | | | | | | |

In the quarter in which prize firing takes place the allowance must be modified, one nature of charge and projectile being used throughout. *See* p. 434. Special provisions.

The restriction as to firing common shell filled with time fuzes (Circular No. 58 S. 18, Nov. 1872) from heavy guns has now been withdrawn.

The ammunition allowed for practice is to be so apportioned that the men are properly instructed in the use of the great guns and small arms.

In the first reserve district ships the allowance to be for as many guns as can be provided with a full crew, the riggers, top riflemen, and marine small arm men being included.

**1.** The ammunition expended for qualifying men as acting seamen gunners is allowed in addition to the above. Act. S. G.

**2.** Every gun having a full crew of 10 men and above is to be considered a revolving gun. Revolving gun.

**3.** The 7-pr. M.L. is to fire one double shell with 4 oz. charge every six months, in lieu of 1 common shell filled with full charge. It is to be fired in the first quarter of the half year. 7-pr. gun.

The allowance for field guns should be fired from the field carriage on shore, but if this is not practicable, it must be fired from a boat. Where there is an opportunity of firing from the field carriage on shore six months' allowance may be expended and none fired in the following quarter. Field gun.

**4.** The 7-pr. is not to be used for short practice if there is a 9-pr. or 12-pr. on board. When there is more than one gun of the same nature on board from which short practice may be fired it is to be distributed among them. Short practice gun.

**5.** Exceptional projectiles, as shown in the table, are to be fired in lieu of an equal number of shot or empty shell in the proportion of one of each named projectile for four heavy or revolving guns, or for four pairs of light broadside guns. Exceptional projectiles.

The projectiles for light guns mounted on the upper decks of ironclads are not to be considered as exceptional; the allowance given in the table being the whole allowance for a pair of guns.

Exceptional projectiles are not to be expended in the quarter in which prize firing takes place.

In vessels with less than four guns of the same nature, the allowance of exceptional projectiles will be as follows:—

For three guns, one of each named projectile each quarter.
„ two „ „ „ half-year.
„ one „ „ „ year.

Exceptional projectiles.

In the latter cases the exceptional projectiles are to be fired in the first quarter of the named period, unless prize firing should take place in that quarter, in which case they are to be fired in the next quarter.

Palliser shot.

**6.** Where there are no Palliser shot allowed empty Palliser shell to be fired in lieu.

Rockets.

**7.** Rockets are not to be fired if more than 5 years old.

Nordenfelt guns.

**8.** Except for quarterly exercise the Nordenfelt guns are only to be fired in cases of absolute necessity.

Or if the full proportion of 10,000 rounds is not allowed for each gun the supply is not to be reduced below $\frac{7}{10}$ of the proportion carried.

Gatling.

**9.** The supply of ammunition for the ·45 Gatling is not to be reduced by practice below 7,000 rounds per gun. A portion of the practice is to take place from the gun mounted as it would be in action.

Small arm.

**10.** If good opportunities offer for firing at a rifle range, the whole or any portion of the year's allowance of rifle ammunition may be expended, provided that the directions, p. 174, Rifle and Field Exercise Book, 1877, be observed.

# CHAPTER XXIV.

## HASTY INTRENCHMENTS AND FIELD FORTIFICATIONS.

### General Remarks.

Hasty intrenchments and field fortifications are constructed to place a defensive force in a position of advantage to resist attack.

The issue of an attack is, under modern conditions of warfare, mainly determined by fire-action, *i.e.*, the fire of a stationary line of men armed with breech-loading rifles is so deadly, that it will be impossible for an attacking force to close with a defensive force (unless the attack partakes of the nature of a surprise, or is made under most exceptionally favourable circumstances) until this latter has become demoralized by the assailants' fire, or has suffered such loss that the volume of its own fire is materially diminished.

Consequently, since an attack is repulsed by fire, and since success in an attack can only be gained by fire, every fortification should fulfil, to as great an extent as the time and means available for its construction will permit, the following three conditions:—

1. It should cover or protect the defenders from the fire of the enemy.
2. It should enable the defenders to see the enemy, and use their weapons with effect over the whole ground within range of fire, with the least possible exposure to themselves.
3. The assailant's access to the position should be obstructed and difficult, in order that the attackers may be kept as long as possible under the fire of the defenders.

To obtain the fulfilment of the *first* of these conditions, existing cover, (such as banks of earth, walls, houses, &c.) is utilised, or a bank of earth ("*parapet*") is thrown up, the earth being obtained either from an excavation in front of the parapet ("*ditch*"); or from an excavation in rear of the parapet ("*trench*"); or from both.

The *second* condition is fulfilled by clearing the ground in front of the firing line (*i.e.*, generally in front of the parapet) of everything that may obstruct the fire of the defenders and the

*Third*, by arranging "*obstacles*" to the approach of the enemy.

## WORKING PARTIES AND TIME REQUIRED FOR THE CONSTRUCTION OF EARTHWORKS.

The time which it will take to construct a defensive work will vary greatly with the circumstances of each particular case, with *e.g.*, the nature of the ground, the state of the weather, the condition of the men, &c., but an approximate calculation of the time required may be made by assuming the following data:—

Rate of excavation in different soils.

In easy soil.

A man of ordinary stature and physical development can excavate one cubic yard (27 cubic feet) of earth in one hour in *easy* soil (in soil, that is, which can be dug out with a shovel only, and does not require to be first loosened with a pick) and can throw the earth a mean distance of 12′ horizontally or 6′ vertically, or any compound of these distances, say 6′ horizontally and 3′ vertically.

In difficult soil.

In *difficult* soil, where each shovelful has to be loosened with the pick before it can be excavated, a man can only dig half a cubic yard in one hour, or, say, 13 cubic feet; and

In moderate soil.

In *moderate* soil, where some picking is required, he will be able to excavate 20 cubic feet per hour.

Amount that can be excavated in a day or in a shorter period.

A man should be able to continue working at these rates for three or four hours. If he is working for a day of eight hours, two hours of the eight must be allowed for meals, standing easy, &c., so that in the eight hours he cannot be expected to excavate more than—

| | | | |
|---|---|---|---|
| 160 | cubic feet | in | easy soil. |
| 120 | „ | „ | moderate soil. |
| 70 | „ | „ | difficult soil. |

On the other hand, if he is only to work for a very short time (one to two hours), he will be able to accomplish a proportionately larger task.

Apportionment of work.

In distributing a working party it is best, if possible, to give each man a definite task, letting him know that when he has completed his portion, and it has been passed by the superintending officer, he may leave off work; or if working pay be given, it will be better to pay a man, not by the day, but by the amount of work he gets through. A little experience will enable an officer to determine how much may be reasonably expected from a man in a given time under given circumstances.

of
ly to
1.

It will rarely be advantageous to place more than one row of diggers in a trench or ditch, if all the earth has to be

thrown out on one side. Where some of the earth has to be placed on one bank and some on the other, two rows may be profitably employed.

Diggers and pickers employed in same excavation.

When it is desired to complete a work very rapidly and labour is plentiful, a row of pickers may be detailed as well as a row of shovellers if the soil be *difficult*. The pickers and shovellers in this case are not to work simultaneously, but are to relieve one another at short intervals, say of four or five minutes or less. As each party by this plan gets frequent short intervals of rest, the men should work with greater vigour when actually using their tools.

Shovellers sometimes required.

Where the mean distance which the earth has to be thrown exceeds 12′ horizontally or 6′ vertically; a row of shovellers must be detailed to pass it on from the place to which the diggers throw it, to its final place in the parapet; and in any case it will be desirable to have a certain number of *rammers* on the parapet to build it up in the desired shape, and by ramming down the earth as it is thrown up make the covering bank more compact, and therefore of greater resisting power.

Rammers.

Foissonement.

Earth when excavated increases in bulk; this increase is termed its *foissonement*, and in some natures of soil this *foissonement* may be as much as $\frac{1}{7}$th or even $\frac{1}{6}$th of the original volume. Usually, however, it will be only about $\frac{1}{10}$th or $\frac{1}{12}$th. Thus an excavation of which the volume is 100 cubic feet will frequently supply earth for a parapet of which the volume is 110 cubic feet.

Area of excavation to be equal to area of parapet.

As moving earth to any distance right or left of the spot from which it is excavated will involve great labour, the area of a parapet at any point should be approximately equal to the area of the excavation on the same *profile;* understanding by the term profile a section formed by a vertical cutting plane at right angles to the length of the parapet.

Interval between diggers.

Unskilled men employed as diggers should be placed at intervals of 5′ to 6′. Skilled men may be placed closer together.

## PROVIDING COVER.

### SHELTER TRENCHES.

The most rapidly constructed cover is obtained by digging "*shelter trenches*" (shallow trenches in which cover is afforded to men kneeling or lying down, the excavated earth being formed into a bank or parapet in front, over which the defenders can fire).

English shelter trench.

Fig. 1, Plate I.* (the shelter trench given in the Army Field Exercise Book) is a trench $2\frac{1}{2}'$ wide, $1\frac{1}{2}'$ deep, the earth forming a parapet $1\frac{1}{2}'$ high; a "*berm*," or narrow space of ground $1\frac{1}{2}'$ wide, being left between the parapet and trench. This trench can be completed by a line of men at two paces (5′) intervals in half an hour. Under favourable circumstances, when there is no long grass to be cleared away, or other obstacle to the immediate commencement of the work to be removed, the trench can be finished in much less time.

Figs. 2 and 3, Plate I, are improvements of Fig. 1. In Fig. 2 the trench is widened to 5′, in Fig. 3 to 8′; the parapet remaining of the same height, $1\frac{1}{2}'$, but thickened by the additional earth obtained. Time for completing Fig. 2 one hour; for completing Fig. 3 two hours.

Triangular shelter trench.

Fig. 5, Plate I., is a triangular shelter trench. Trench 1′ deep, parapet $1\frac{1}{4}'$ high. Owing to its form this trench takes as long to construct as Fig. 2, and affords less cover; but it presents a less obstacle to the advance across it of cavalry or artillery.

## MUSKETRY TRENCHES.

Definition of term musketry trench.

By deepening the trenches and increasing the height of the parapets shelter trenches may be converted into musketry trenches (trenches in which men stand to fire).

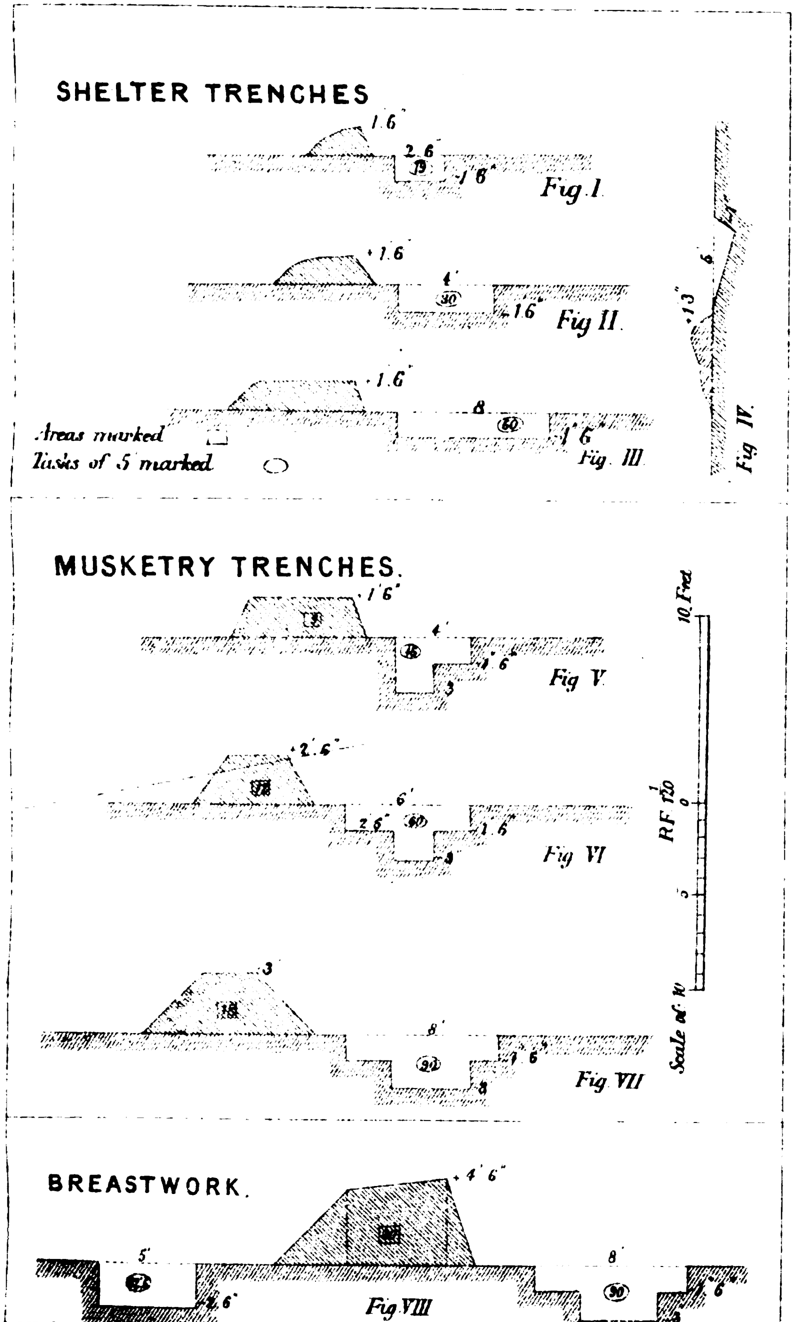
Advantages and defects of musketry trenches.

These afford better cover; but would prove a greater hindrance to the movement of troops over them, and if captured by the enemy would afford him better cover against the fire of works or troops in a second line of defence and would place him in a better position to repulse an attempt to retake them. It will therefore depend upon the circumstances of each particular case whether it will be advisable or not to substitute musketry for shelter trenches.

Fig. 5, Plate I., is a trench 4′ wide at the top, 3′ deep in front, $1\frac{1}{2}'$ deep in rear, with a parapet $1\frac{1}{2}'$ high. It gives $4\frac{1}{2}'$ of cover to a man standing in the deep part in front and firing over the parapet, and complete cover to a man sitting on the step in rear. Time for construction, men at 5′ intervals, $1\frac{1}{2}$ to 2 hours.

Fig. 6, Plate I., is Fig. 5 improved by piling the earth of the rear part of the parapet on to the top of the front part, thus making the parapet $2\frac{1}{2}'$ high, and by digging a step $2\frac{1}{2}'$ wide and $1\frac{1}{2}'$ deep in front of the deep part of Fig. 5. This trench gives 4′ of cover to a man standing on the front step and firing over

* "Notes for the Plates," giving an explanation of the symbols used, will be found on page 472.

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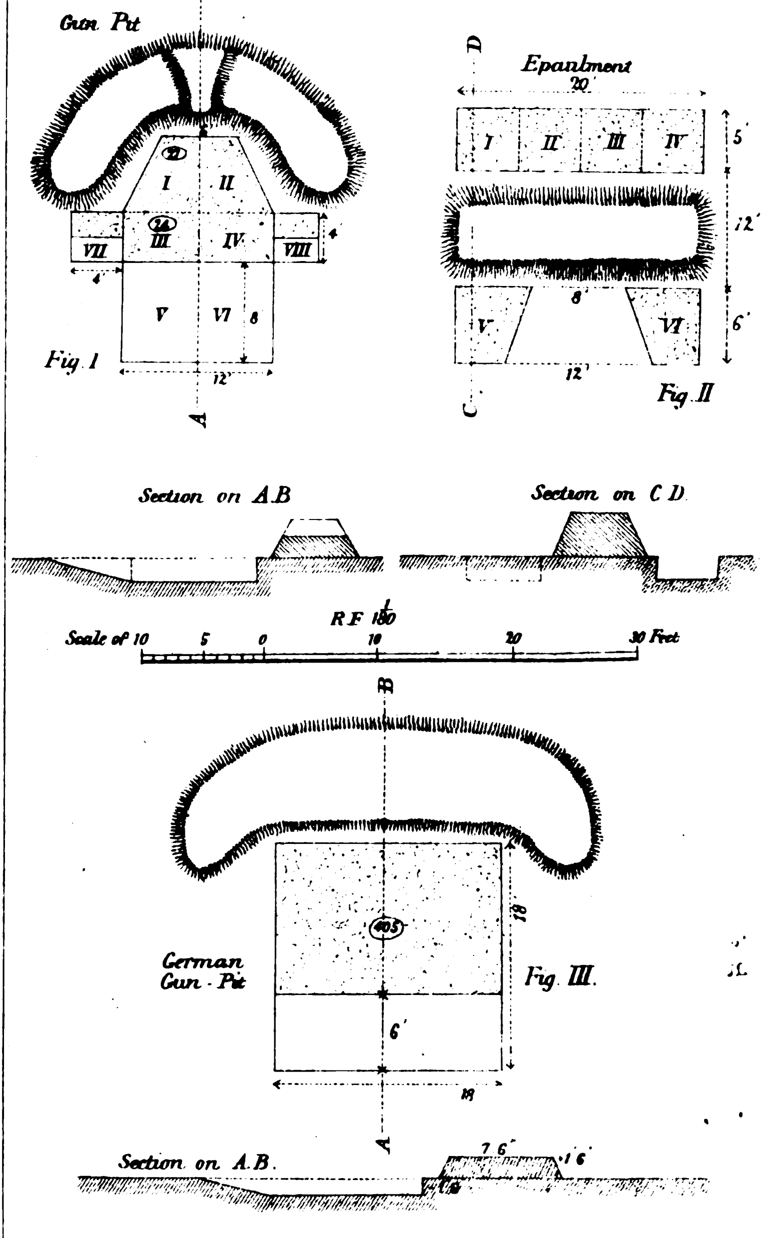
# COVER FOR GUNS.

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the parapet, and 5½ of cover to a man standing in the deep part of the trench. If great depression of fire be required, as, for instance, when the trench is on the slope of a hill, the top of the parapet may be cut away, as shown by the dotted line in the figure. Time 2 to 2½ hours.

Fig. 7, Plate I., is Fig. 6 improved by widening the deep part of the latter from 1½′ to 4′, and by increasing the mean thickness of the parapet from 4′ to 6′, and its height from 2½′ to 3′. This gives 4½′ of cover to a man standing on the step and firing over the parapet, and 6′ of cover to men standing in the deep part of the trench. Time 3½ to 4 hours.

## Breastwork.

**Definition of term breastwork.**

If a sufficient number of men are available, a "*breastwork*" (where the men standing on the ground fire over a bank of earth breast high in front of them) may be completed in the time taken to construct the trench shown in Fig. 7 (3½ to 4 hours).

In Fig, 8, Plate I., the trench is the same as in Fig. 7, but the parapet is increased to a height of 4½′, and is made 5′ thick at the top; the additional earth being obtained from a ditch in front, which can be begun simultaneously with the trench, one row of diggers working in the trench, another row in the ditch. In this case the berm is left 3′ wide, in order that the men firing may have convenient standing space.

**Interior slope revetted.**

The "*interior*" or inner slopes of parapets breast high should be "*revetted*" whenever possible; *i.e.*, they should be faced with some material which will retain the earth at a steep slope. This should be done in order that the men may be able to stand nearer to the covering mass of earth; when they will be able more conveniently to use it as a rest for their rifles, and will at the same time be better protected by it. In the construction of the breastwork described above the revetment might be arranged by the men digging the ditch, as they have a lighter task to accomplish than the diggers in the trench.

## Cover for Artillery.

Cover, similar to that provided for infantry by the shelter trench, may be constructed for guns by excavating "*gun-pits*" or by throwing up "*epaulments*."

**Gun-pit.**

In a "*gun-pit*" a shallow pit is dug, in which the gun is worked; the earth excavated being formed into a low bank in front.

**Epaulment.**

In an "*epaulment*" the gun is worked on the natural surface of the ground and is covered by a bank; the earth for which is mainly obtained from a ditch in front or on both sides of

When gun-pit and when epaulment should be used.

Where the nature of the soil gives a firm wheel base at the bottom of the pit and where there is no prospect of rain rendering the latter impracticable for the gun detachment to work in, a gun-pit will be the quickest method of obtaining cover; but in all cases where there is any chance of the ground proving unsuitable for a pit an epaulment must be constructed.

English gun-pit.

Fig. 1, Plate II., is a gun-pit which can be excavated by seven men in one hour. The pit is 2′ deep and of the shape and dimensions shown in the plan. The covering bank is 3′ high, except at the part over which the gun fires, where it is only 1½′ high. At the sides are wings (for the better protection of the gun's crew when not actually serving the piece) consisting of trenches 4′ wide, 1½′ deep in front, and 3′ deep in rear. The Roman figures and dotted lines indicate the tasks of the several men of the working party. Should protection against very oblique fire be required covering banks of earth must be placed across the ends of the wings.

Simple forms of epaulment.

Fig. 2, Plate II., is an epaulment for protection against front fire. The earth for the bank is obtained from a ditch in front (20′ long, 5′ wide, and 2′ deep), and from two trenches, one on either side of the gun (5′ long, 6′ wide in front, and 4′ in rear and 2′ deep), in which those of the gun's crew not actually engaged in working the piece can find cover.

German gun-pit.

Fig. 3, Plate II., is a gun-pit in use in the German service. The pit itself is 12′ square and 1½′ deep, a ramp 6′ long (slope ¼) leading into it from the rear. The excavated earth forms a covering bank 1½′ high and about 12′ thick, which, if necessary, may be continued some way round the sides of the pit. Eight men can make the pit in one hour.

In this pit the gun fires *en barbette*, instead of as in the English pit through an opening, or roughly shaped embrasure in the bank. In most cases in the field the former arrangement is much to be preferred, as it gives full lateral range to the gun instead of confining it to one direction of fire. The protection afforded however is not so complete, and for flanking a special line the English type seems preferable.

Gun batteries.

Gun-pits or epaulments should, when possible, be placed from 25 to 30 yards apart; but, if the available space be limited, they may be made closer together, in which case it will often be found convenient to connect them into a battery.

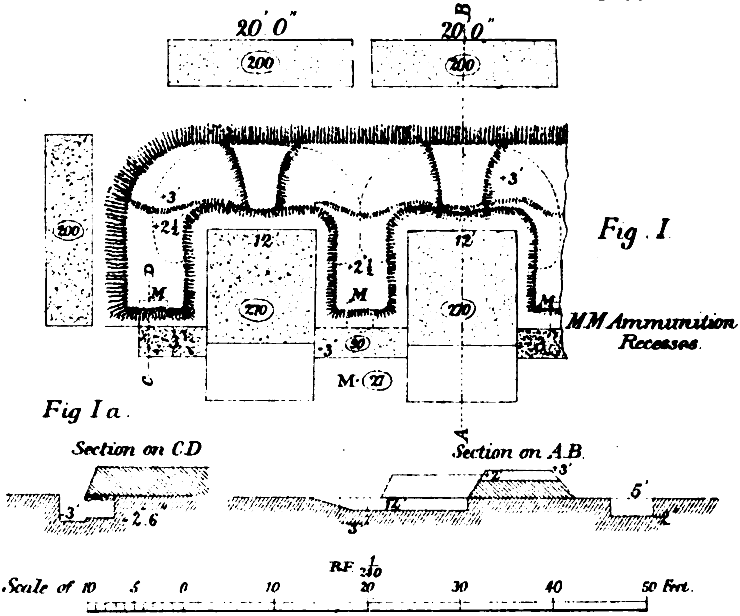
Sunken battery.

Fig. 1, Plate III., shows the plan and section of a "*sunken battery*," formed by connecting the wing trenches of gun-pits excavated at central intervals of 24′. Time 1 hour.

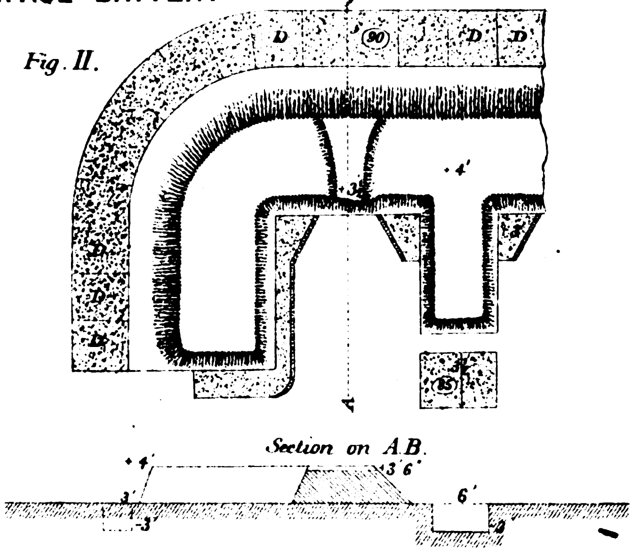
Surface battery.

Fig. 2, Plate III., shows the plan and section of a "*surface battery*," formed by a continuous epaulment with traverses between the guns. Time, 3–5 hours.

# GUN PITS CLOSED INTO A BATTERY.




## SURFACE BATTERY



## Cover for the Limbers of Field Pieces.

If no natural cover for the limbers of guns sheltered in pits or behind epaulments can be found at a convenient distance in rear, either—

1. The limber boxes may be taken off and placed in recesses made for them in the gun-pit or in the trench of the epaulment; or
2. Limber pits may be excavated.

Fig. 5, Plate VII., shows the plan and section of a limber pit, 6′ square at the bottom and 4′ deep, with a ramp 16′ long slope $\frac{1}{4}$) leading into it; the excavated earth being formed into a covering bank 3′ high, 5′ wide, and 10′ long at the top. Five men can complete such a pit in from 2 to 3 hours. Limber pit.

Fig. 1a, Plate III., shows the section of a recess made to receive a limber box. Recess for limber box.

## Platforms.

Whenever guns are likely to be worked on the same ground for any long periods, it is desirable that *platforms* should be laid down, both to facilitate the working of the piece and to render accurate firing possible. Unless some kind of platform be constructed ground soon becomes cut up and rutted by the recoil of the gun; when the labour of running the gun up will be increased, and the nice training of the piece rendered very difficult. Reasons for laying down platforms.

The kind of platform to be constructed must depend in every case upon the description and amount of material at hand. If nothing else be procurable three stout planks may be laid down; one for each wheel of the gun carriage and one for the trail to recoil along. If the necessary material be forthcoming, however, every gun platform should have:—

Conditions platform should fulfil.

1. Sufficient length to allow of the gun recoiling without the wheels running off;
2. Sufficient width to permit of a moderate amount of traversing;
3. Sufficient strength to prevent it bending under the weight of the guns, and to allow for a considerable amount of wear and tear.

A floor of stout planks placed transversely, and resting on five beams or *sleepers* placed longitudinally, will form a sufficiently strong platform for an ordinary field gun; and a surface 15′ long and 9′ wide in the clear will afford sufficient space for the recoil and working of the piece. The planks may be kept in their places by being nailed to the sleepers; or by Construction of platform.

means of a ribband, or strip of wood, laid along the edges of the planks on each side of the platform, and fastened to the sleepers by means of rack lashings.

When it is intended to use the platform for a mortar, the former should be strengthened (to enable it to withstand the violent action of the piece when fired) by placing three transverse sleepers under the longitudinal beams.

## Parapets with Ditches, and with Ditches and Trenches.

**When parapet with ditch must be employed.**

The shelter and musketry trenches described in the preceding pages supply the most rapidly constructed cover that can be created, and afford very efficient protection against musketry fire. If circumstances, such as the presence of water immediately below the surface, or the general damp or marshy nature of the soil, render the employment of a trench inconvenient or impossible, a parapet must be formed with earth obtained from a *ditch* in front. Or when the parapet is to be made sufficiently substantial to afford protection against artillery fire, the earth for it will be obtained from a ditch in front; or, more frequently, partly from a ditch in front and partly from a trench in rear.

A parapet is generally bounded by the slopes described in the following sections:—

**Superior slope.**

The top of a parapet is given a slope to the front to allow men firing over it to depress their fire. This slope is called the "*superior slope*," (*a*—*b*, Fig. 1, Plate IV.). This superior slope should be so regulated that fire directed along its surface may pass not more than 3′ above the outer edge of the ditch. A slope of $\frac{1}{6}$ will usually fulfil this condition, but to avoid weakening the parapet it is better to make it more gentle ($\frac{1}{7}$ or $\frac{1}{8}$), and in no case should it be steeper than $\frac{1}{4}$.

**Exterior slope.**

The "*exterior slope*," (*b*—*c*, Fig. 1, Plate IV.), is the slope extending from the outer end of the superior slope to the ground. As this is the slope most exposed to fire it should not be made steeper than what is called the *natural slope of the earth.* With the generality of soils this slope will be $\frac{1}{1}$; but with very loose earth or sand, or when it may have to resist a prolonged or heavy bombardment, the slope should be made more gentle ($\frac{3}{4}$ or $\frac{2}{3}$).

**Banquette.**

The "*banquette*," (*d*—*e*, Fig. 1, Plate IV.), is a raised pathway or terrace on the inside of the parapet to enable men to fire over the latter. It is usually made 4′ 6″ below the top

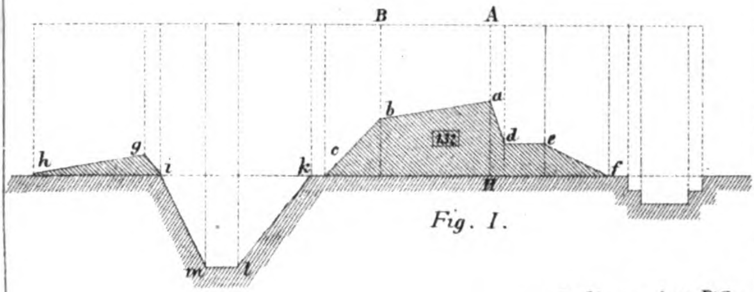



Fig. I.

Profile against Rifles
Stiff Soil

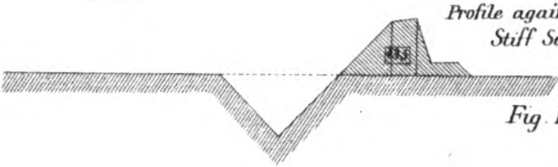



Fig. II.

Parapet with Field Casemate.

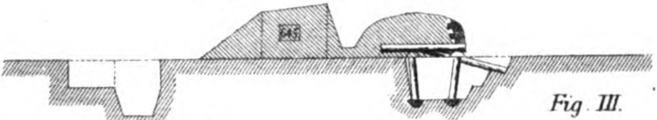



Fig. III.

Scale for Figs. I. II. III. $\frac{1}{240}$

Machine Gun Blindage

Section on A.B.

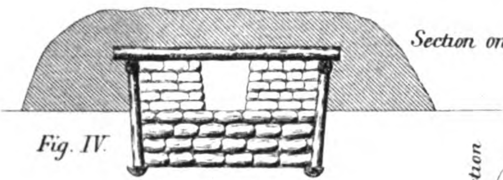
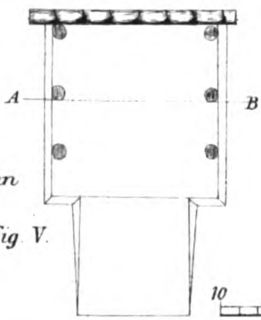


Fig. IV.




Ground Plan

Fig. V.

Longitudinal Section

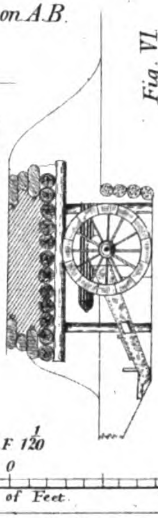
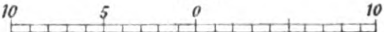


Fig. VI.

R.F. $\frac{1}{120}$




Scale of Feet.

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To face page 454.

of the parapet, and 3′ wide if for a single rank, or 4′ if for a double rank of men.

The "*interior slope,*" (*a—d*, Fig. 1, Plate IV.), is the slope extending from the inner end of the superior slope to the banquette. This slope is made as steep as possible ($\frac{3}{1}$ or $\frac{4}{1}$) to enable the men on the banquette to stand close to the covering mass of the parapet, and more conveniently use the top of the latter as a rest for their rifles. **Interior slope.**

The *slope of the banquette,* (*e—f*, Fig. 1, Plate IV.), extends from the banquette to the ground. To enable men to ascend and descend easily, it is usually not made steeper than $\frac{1}{2}$. Steps may be substituted for it, if they can be revetted to prevent them being trodden down. **Slope of the banquette.**

The *crest,* (*a*, Fig. 1, Plate IV.), of a parapet is its highest line, *i.e.*, the intersection of the superior and interior slopes. This crest is also sometimes called the "*interior crest.*" **Crest.**

The *exterior crest,* (*b*, Fig. 1, Plate IV.), is the intersection of the superior and exterior slopes. **Exterior crest.**

The "*thickness,*" (A—B, Fig. 1, Plate IV.), of a parapet is measured horizontally between the crest and exterior crest. This thickness is usually made $1\frac{1}{2}$ times the greatest penetration of the projectiles it is intended to resist. Consequently a parapet exposed to musketry fire should be at least 3′ thick; to the fire of light guns (such as the English 9-pr.) from 6′ to 9′; to the fire of heavier field guns (such as the English 16-pr.) 9′ to 12′; and to the fire of guns of position, 12′ to 18′ thick. These thicknesses must of course be modified to meet exceptional circumstances. **Thickness.**

The "*command,*" (*a*—H, Fig. 1, Plate IV.), of a parapet is the vertical height of the crest above the ground on which it is constructed. The greater the *command* of a parapet the better will evidently be the cover it will afford. Six feet is the least command which will screen the ground behind—when the plane of the site of the work is horizontal—during the close attack; but to allow for the parapet being reduced in height by artillery fire it will generally be better to increase its height to $7\frac{1}{2}$′ or 8′, and such is, therefore, the command usually given to parapets in the field when time permits. On the other hand a command of 10′, or at the very outside of 12′, should never be exceeded; since, as the volume of the parapet increases rapidly with the height, the time and labour of execution would become too great for a field fortification. **Command.**

llowance to e made for the ll of projec- les.

In determining the height of a parapet allowance must be made for the angle of descent of the enemy's projectiles. The angle of fall of the Enfield bullet at 500 yards is $\frac{1}{46}$; at 800 yards $\frac{1}{19}$; of the Martini-Henry bullet, at 300 yards $\frac{1}{142}$; at 500 yards $\frac{1}{96}$; of the 9-pr. M.L.R., at 3,000 yards about $\frac{1}{5}$. Assuming, therefore, the ground to be level, a parapet 8′ command would only afford cover to a man 6′ high, against a battery 3,000 yards away, to a distance of 10 feet behind the crest line. Complete protection against artillery fire can, in fact, only be obtained by providing blindages, or other form of bomb-proof accommodation (Fig. 3, Plate IV.).

Glacis.

A "*glacis*," (*h*, *g*, *i*, Fig. 1, Plate IV.), is a bank of earth thrown up at the top of the counterscarp to raise up the assailant into the line of fire of the defender, when the top of the counterscarp cannot otherwise be properly defended without making the superior slope of the parapet too steep.

Escarp.

The "*escarp*," (*k*—*l*, Fig. 1, Plate IV.), is the slope of the ditch nearer to the parapet.

Counterscarp.

The "*counterscarp*," (*m*—*i*, Fig. 1, Plate IV.), is the slope of the ditch more distant from the parapet.

The steeper the *escarp* and *counterscarp* are made, the greater will be the obstacle the ditch will present to an assailant. If made too steep, however, the slopes will soon fall in under the influence of weather. They can, therefore, be rarely made more than $\frac{3}{1}$, and frequently they must be even more gentle than this.

Triangular ditch.

Sometimes the escarp and counterscarp are prolonged until they meet, when a triangular ditch is formed.

Width and depth of ditch.

The *width* of the ditch at the top should be at least 12′, and its *depth* at least 6′, in order that it may present something of an obstacle to the assailant.

For reasons before explained, it is desirable that the area of the ditch on any profile should be approximately the same as the area of the parapet on the same profile, and either the width or the depth may be altered, as circumstances may render advisable, to obtain the required area.

Fig. 4, Plate IV., is a sectional elevation of a blindage for a machine gun. Fig 5, Plate V., is the plan, and Fig. 6 is a longitudinal sectional elevation of same blindage.

Fig. 2, Plate IV., is a parapet affording defence against musketry fire.

Fig. 1, Plate IV., is a parapet with ditch and trench affording protection against artillery fire.

## Special Protection for the Heads of Men firing over a Parapet of any kind.

The heads and shoulders of men firing over a parapet of any kind are necessarily exposed. It is not possible to protect them entirely from artillery fire, but they may be covered to some extent from musketry, case shot, or splinters of shell.

**Height of portions of parapet increases.**

In the case of shelter trenches, a little extra height may be given to the portions of parapet between every two rifles, and in larger works a thin earth screen, with channels through it for rifles, may be built up on the top of the parapet; or

**Logs used as protection.**

Logs may be placed on the crest resting on sand bags or other materials (Fig. 6, Plate VII.), to raise them sufficiently high to leave a space for rifles to fire through; or

**Loopholes, brushwood, and board.**

Brushwood loopholes (Fig. 7, Plate VII.), or board troughs may be embedded in the crest of the parapet. These latter are made by nailing together, so as to form a frustrum of a square pyramid, four pieces of plank each $2\frac{1}{2}'$ long, $10''$ and $5''$ broad at the ends respectively. The apertures will be about $8''$ and $3''$ square. These brushwood and wooden loopholes will be sunk in the parapet of the trench, rifle pit, &c., near the top, where it is $2\frac{1}{2}'$ thick, with the smaller opening on the outside.

## CLEARING THE GROUND.

**Importance of clearing ground.**

The importance of providing a clear field of view and fire in front of a defensive line, whether the men be behind cover or not, cannot be too strongly insisted upon. Unless such a clear zone of sufficient depth exists, or can be made within the time and with the means available, a position will rarely be tenable. It has been remarked with perfect truth that if the history of defensive actions be examined, it will be found that for one place which has fallen because the men on the defensive had not sufficient cover, a dozen have fallen because the obstacles to fire in front had not been cleared away. In arranging a position for defence, therefore, the work of clearing the foreground must be undertaken systematically by special parties; and every effort should be made to thus clear the front up to the effective range of rifles, especially on those sections where there may be reason to anticipate that the assailants' most strenuous efforts to close will be made.

The following data will be useful in estimating the amount of labour, time, and tools necessary for clearing ground.

Clearing away trees.

*Felling Trees.*—Two unskilled men with axes can cut down trees of 4, 6, 9, 12 and 18 inches in diameter in about 1, 3, 5, 9 and 15 minutes respectively. Soft wood trees of 2′ or 3′ in diameter can be felled in 20 to 30 minutes by 4 men; but if the trees are of hard wood they will take about three times as long to cut down.

To fell a tree with an axe, begin cutting on the side towards which the tree is intended to fall, and cut in about two-thirds of the diameter; the lower part of the cut being nearly horizontal, the upper surface well sloped upwards so as to free the axe. A few cuts on the opposite side rather above the first cut will then bring the tree down.

Trees may be quickly felled by the use of gun cotton. One pound per foot in girth applied externally, or 2 oz. to 3 oz. per foot in girth in a $1\frac{3}{8}$-inch augur hole bored nearly through the trunk will be sufficient to bring the tree down.

Clearing away hedges.

*Hedges* can be cut down by a line of men at 5 feet intervals in from 5 to 20 minutes; or 10 men will on an average clear 500 yards in 6 hours. They will require 10 billhooks, and will cut forked poles to use in forcing the cut through hedge over to the enemy's side.

Knocking down walls.

*Walls* are most easily knocked down by means of a beam, trunk of a tree, or railway bar worked by 10 to 12 men as a battering ram; charges of 60 lbs. of gunpowder placed at intervals of 12′ will blow down a wall not more than 2 feet thick; or a 14″ brick wall may be breached by $1\frac{1}{2}$ lbs. of gun cotton per lineal foot.

Destroying houses.

*Houses.*—40 lbs. of gunpowder exploded in a central position will blow down a small dwelling house. The task of removing the debris will however generally be a laborious one.

Throwing down banks.

*Earthen banks*, averaging 5 feet high and 3 feet thick, can be thrown down, sufficiently to destroy cover, at the rate of 100 yards in 6 hours by a squad of 10 men, each man being provided with a shovel. If there be trees growing on the bank the roots will greatly increase the labour, and axes and pickaxes must be added, and the task reduced.

Clearing away brushwood.

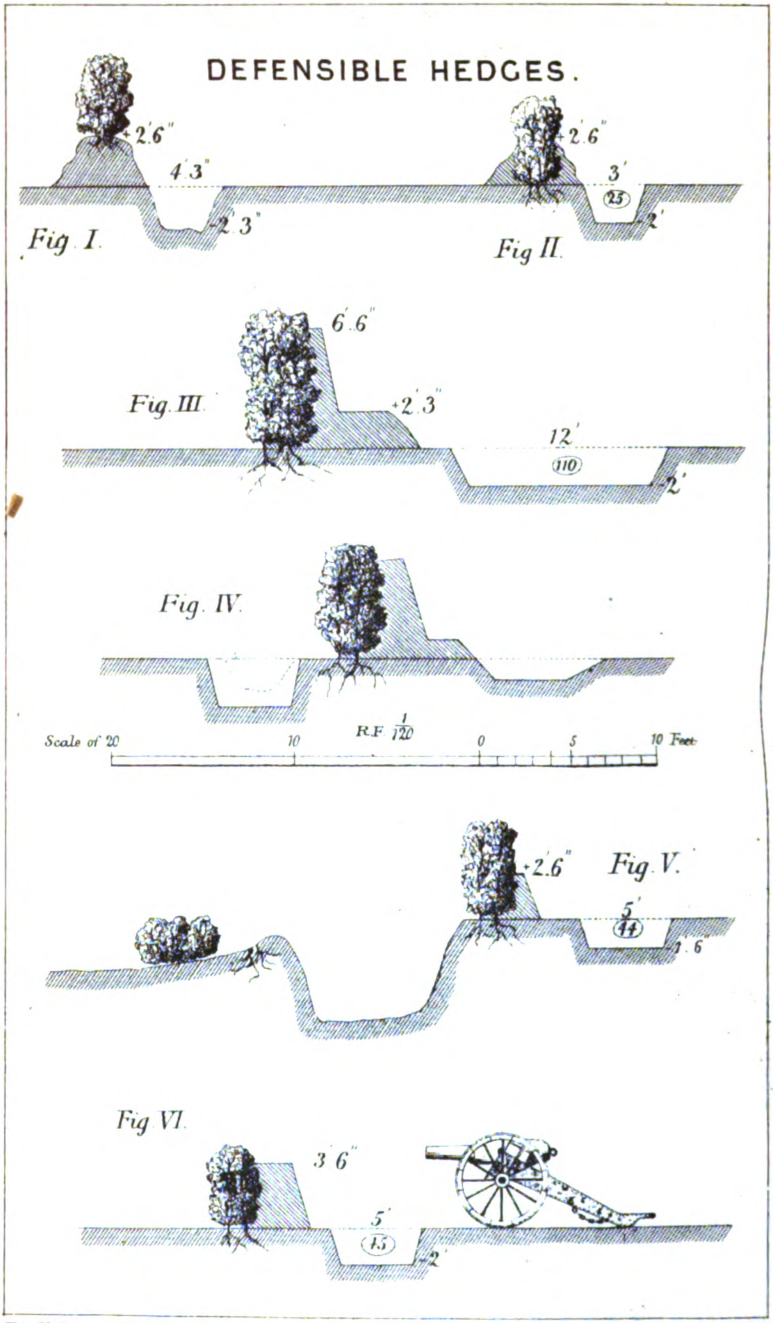
*Brushwood* of five or six years' growth can be cleared away by men extended in line at 5 feet intervals at the rate of about 30 paces (or 25 yards) in 8 hours.

Filling up ditches.

*Ditches* must be filled in; or the inner side must be sloped away to expose the bottom to fire from the rear.

Destroying standing corn.

*Standing corn*, or other crops of high growth, may be destroyed by marching men in line over them.

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To face page 459.

## DEFENSIBLE HEDGES.

Hedges may break the force of a rifle bullet, but they cannot by themselves be considered as affording protection against musketry fire. **Use of hedges.**

They may be utilised, however, according to their growth and position either as :—

1. Obstacles to delay advance of enemy.
2. Screens from view.
3. Revetments, *i.e.*, supports to retain earth at a steep slope.

If intended to serve as an obstacle a hedge had better be left standing. Should it however impede the defenders' fire or view it may be converted into an "*entanglement*" by cutting the stems half through, about 3′ above the ground, bringing the upper part down to the ground, and interlacing and securing the branches with pickets. **Hedge used as obstacle.**

Ditch and bank hedges, with the ditch on the defender's side, can often be used as they stand; the ditch serving as a trench. If the ditch be small or shallow, it may be widened and deepened, the earth being used to thicken or increase the height of the bank; or if none exist to form a parapet supported by the hedge. **Ditch and bank hedges.**

If the ditch be on the enemy's side of the hedge it must be deepened and widened, and the earth thrown over the latter to form a parapet; the hedge serving as a revetment for the exterior slope. In this way the hedge will be useful by diminishing the amount of earth required for the parapet, whilst it will also present an obstacle to assault. **Ditch on enemy's side.**

Fig. 1, Plate V., shows a ditch and bank hedge used as it stands, or with a very slight deepening of the ditch. In this case the hedge acts as a screen; the men firing between the stems.

Fig. 2, Plate V., shows a hedge, without ditch or bank, serving as a screen and partial support to a parapet formed of earth from a trench dug in rear.

Fig. 3, Plate V., shows a hedge used as an exterior revetment to a parapet; the earth for the latter being obtained from a shallow trench in rear.

Fig. 4, Plate V., shows a hedge with a ditch on the enemy's side, widened and deepened, the earth being thrown over the hedge to form a parapet.

Fig. 5, Plate V., shows a deep cut lane, with a hedge on either side, prepared for defence; the one hedge serving as an obstacle, the other an exterior revetment.

Fig. 6, Plate V., shows a hedge utilised as a screen and revetment for a gun epaulment.

## DEFENSIBLE WALLS.

Nature of protection afforded by walls.

Walls afford protection against musketry fire, or the balls of shrapnel; but they will not resist the common shell of field guns unless they are of exceptional thickness, over 3′.

The principal work to be done in preparing walls for defence is to make either loopholes, or notches from the top.

Loopholes.

It will rarely be worth while wasting time and trouble in attempting to make loopholes of any regular shape. They should, however, appear from the outside as narrow horizontal or vertical slits (generally about 3″ wide); horizontal when a wide lateral range for grazing fire is desired, vertical when it may be necessary for the defenders to elevate or depress their fire to any considerable extent; while internally they should be made with a splay to allow of such lateral range or elevation and depression as may be required.

Two unskilled men will make a loop-hole in a 14″ brick wall in 10 minutes, or in a 25″ brick wall in 25 minutes, using a crowbar or pickaxe, the former being the most convenient implement.

A notch about 1′ or 1½′ can be cut down from the top of a wall in about 5 minutes.

[illegible] of loop- [illegible] above [illegible]

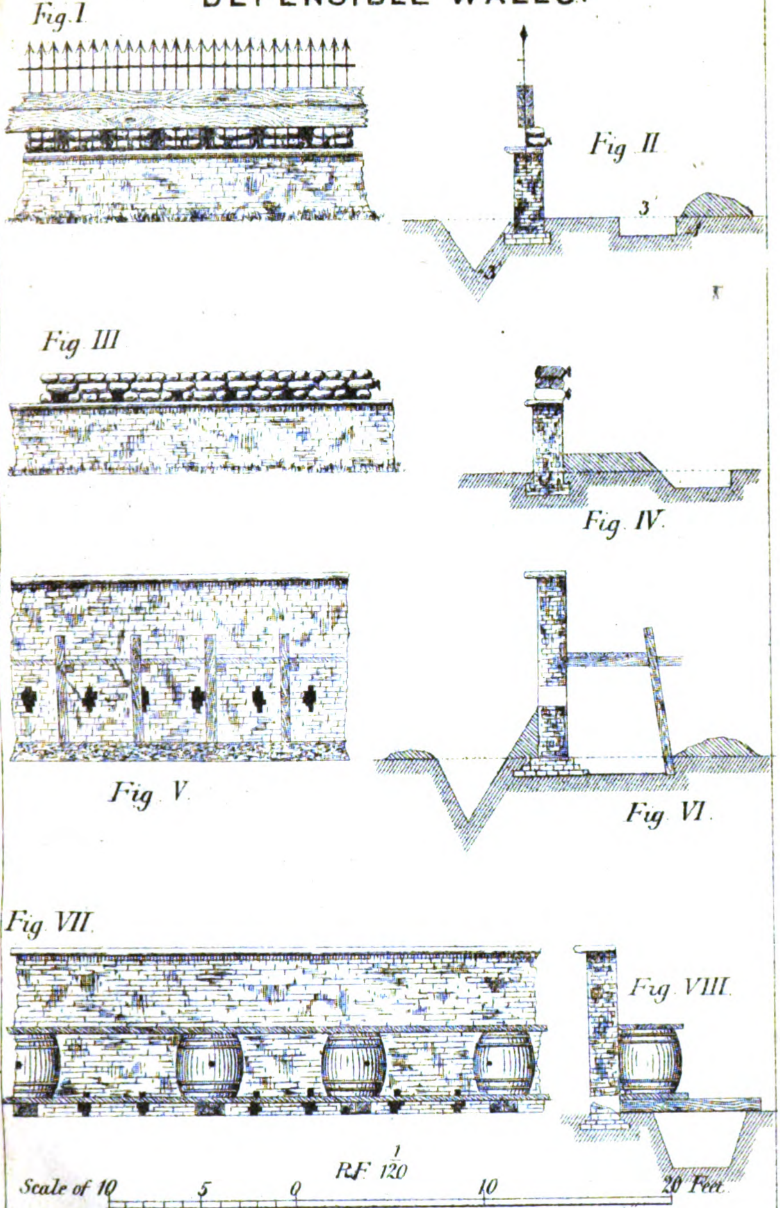
Loopholes should be at such a height above the ground immediately in front of them that the enemy will not be able to fire through them should he succeed in reaching the wall; they should therefore be either close to the ground outside (1′ to 1½′ above it), in which case a trench must be dug inside to accommodate the men firing through them; or else the loopholes should be at least 6′ above the ground outside. When it is necessary to make the loopholes 4′ or 4½′ above the level of the ground outside a ditch must be dug in front of the wall (Figs. 6 and 2, Plate VI.) to prevent the assailant making use of them.

[illegible] for [illegible] men.

If men are to fire over the top of a wall their heads should be protected by a log resting at intervals upon sand bags or bricks, or by sand bags only (Figs. 3, 6, 8., Plate VI.).

Figs. 1 and 2, Plate VI., show a wall with railings, prepared for defence by fastening timber inside and outside the

# DEFENSIBLE WALLS.

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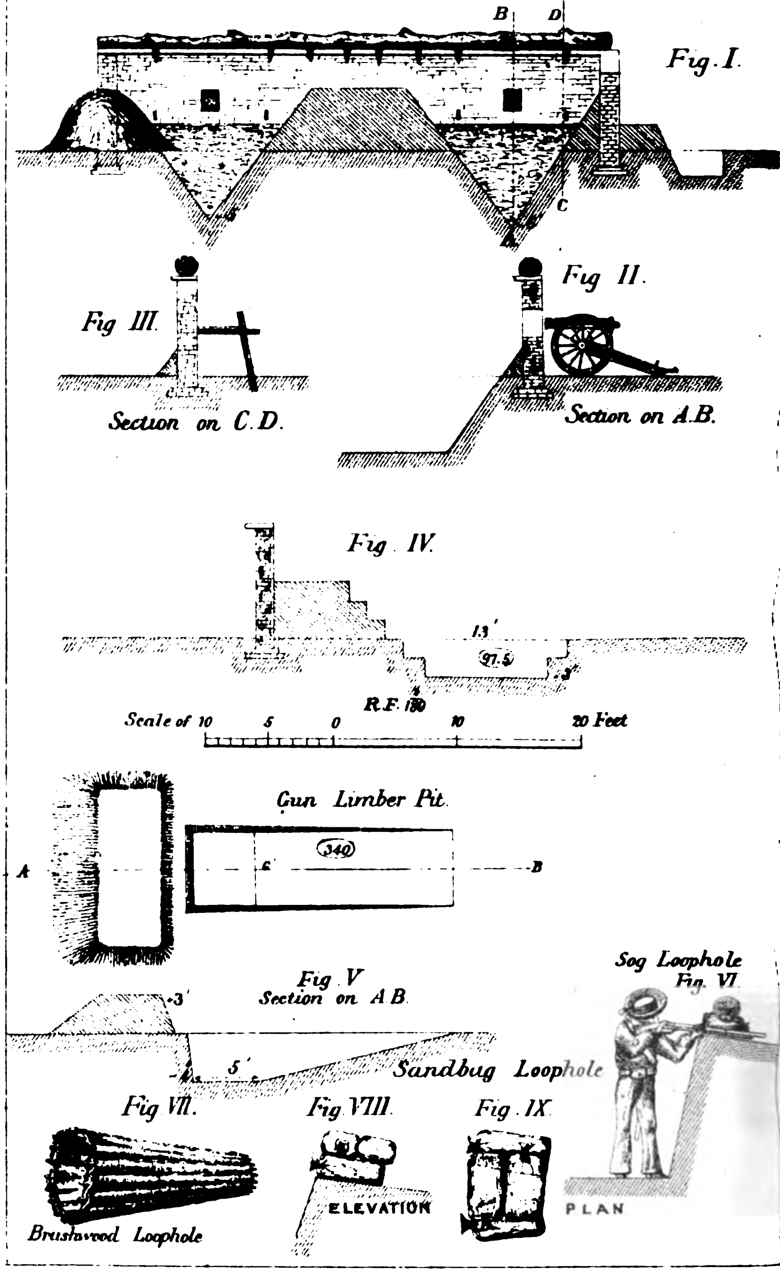
# DEFENSIBLE WALLS.

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latter, and making sand bag loopholes below the timber. A ditch is dug in front to prevent the enemy closing, and a trench in rear to improve the cover. **Protection for heads of men.**

Figs. 3 and 4, Plate VI., show a low wall with sand bags piled on the top, and a trench dug in rear, forming a low banquette, on which men kneel to fire.

Figs. 5 and 6, Plate VI., show a wall 10′ high, arranged for two tiers of fire.

Figs. 7 and 8, Plate VI., show a wall 9′ high, with another arrangement for giving two tiers of fire.

If a wall is to give complete protection against artillery fire it must be strengthened by a bank of earth 6′ to 8′ thick, piled up inside (Fig. 4, Plate VII.), or by a screen of the same thickness in front. (Figs. 2 and 3, Plate VII.)

When this latter plan is adopted it is very desirable that the excavations both in front of and behind the screen should be flanked. Figs. 1, 2, 3, and 4, Plate VII., show how an existing projecting wall may be utilised for this purpose. For flanking fire Gatling guns would be very serviceable, and in Figs. 1 and 3, Plate VII. the necessary arrangements for employing them to advantage are shown.

## OBSTACLES.

"*Obstacles*" are placed in front of a defensive line in order to impede and retard the advance of an assailant, and so keep the latter exposed for as long a time as possible to the fire of the defenders. It will most rarely happen that obstacles can be arranged so as to be insurmountable, but any expedient which will delay the onward rush of an attacker, even though it be but for two or three minutes, may prove of the greatest value. The assailant may have suffered severe loss before he reaches the obstacle, and the additional loss which may be inflicted upon him while he is endeavouring to force his way through, may turn the scale, and induce him to relinquish the assault. In a close country especially, where a long range cannot be secured, and an enemy advancing to the attack has consequently to traverse only a short distance under fire, and also during a night attack *obstacles* will be particularly valuable.

The more an obstacle fulfils the following conditions, the more efficient it will be:— **Conditions obstacles should fulfil.**

1. It should be under the close fire of the defenders.
2. It should be screened from the artillery fire, and, if possible, from the view of the attackers, until the latter are close upon it.

3. It should be so constructed that it cannot be cut down, or easily removed by the enemy.
4. It must not afford any cover whatsoever to the assailant. Any obstacle which in any way impedes the fire or view of the defenders will certainly be far more hurtful than useful.

The obstacles which would be most frequently used in the field by a naval brigade are:—

1. Abatis - - - } All constructed of timber.
2. Entanglements - - }
3. Pickets or pointed stakes - }
4. Palisades - - - }
5. Fraises - - - }
6. Military pits; deep and shallow.
7. Wire entanglements.
8. Fougasses; four kinds, namely, common, shell, stone, and self-acting.
9. Inundations.

Abatis. 1. An "*abatis*" is formed of stout limbs of trees, 12′ to 15′ long, laid as close together as possible, with the branches towards the enemy. The butts should be buried in the ground, and secured by stout stakes; or else by logs, laid across several butts. The large branches should be pointed, and the small branches and leaves removed.

Twenty men can make an abatis of two rows, 30 yards long in 6 hours, when the trees are small and close at hand. Unless this latter is the case the construction of an abatis should not be attempted; as the labour of dragging trees from a distance is very great. The party should be provided with 6 felling axes, 2 hand axes, 6 billhooks, 2 hand saws, 2 mallets, and drag ropes.

Wire twisted firmly round the branches of an abatis and left hanging loosely down between, will render it a much more formidable obstacle.

Entanglement. 2. An "*entanglement*" is a kind of abatis formed by cutting trees, brushwood, &c. half through, about 3′ above the ground; bringing the upper parts down to the ground, and interlacing and securing them by pickets. The ends of large branches should be pointed, and weak places strengthened by ordinary abatis.

Pickets. 3. "*Pickets*" are stakes driven firmly into the ground close together, until 1′ or 2′ only project, the upper ends being pointed.

Palisades. 4. "*Palisades*" are a stout description of paling, made of large branches of trees, logs of timber or young trees, split or

sawn into two or more pieces according to their size, pointed at the top, and secured to two horizontal bars or ribands, one nailed to the palisades below the surface of the ground, the other near their top.

5. "*Fraises*" are palisades placed in a horizontal or nearly horizontal position, either on the escarp or counterscarp slope of a ditch. **Fraises.**

6. *Military Pits*, or *Trous-de-Loup*, are pits dug in the shape of an inverted cone or pyramid; with a pointed stake at the bottom. They are of two kinds, *deep* and *shallow*. The former are 6′ in diameter and 6′ deep, and are usually conical; the *shallow* ones are shaped like inverted pyramids, 3′ square, and not more than 2½′ deep. The larger pits should be in parallel rows, the central intervals of the pits in each row being 10′; and the holes in each row should be opposite the intervals between those in the adjacent rows. The earth obtained from the pits should be piled up on the ground in the intervals between the latter, so as practically to increase their depth. **Military pits.**

An objection to the employment of the deep pits is that unless they can be flooded they may form convenient rifle pits for an enemy's skirmishers. The shallow pits, on the other hand, are of such slight depth that an incurrence of this risk is avoided. These latter are placed in rows touching one another, in a zig-zag arrangement. Five rows are usually made; the earth excavated being formed into a covering bank in front.

A combination of *shallow pits* with a *wire entanglement* (described in the following paragraph) forms one of the most formidable and easily constructed obstacles that can be improvised.

One man should dig a deep pit in from three to five hours, or five shallow pits in about three hours.

7. A "*wire entanglement*" is formed by driving stout stakes firmly into the ground, leaving from 1′ to 2′ above the surface, from 4′ to 7′ apart, in rows arranged chequerwise, so as to form a series of equilateral triangles with sides of from 4′ to 7′ feet. Stout wire is twisted round the heads of the stakes so as to mark out the triangles. This obstacle is easily prepared; is little injured by artillery fire; is impassable by cavalry; and will throw attacking infantry into confusion, especially at night. **Wire entanglement.**

8. "*Fougasses.*"—A *common fougass* is a small mine to be fired by fuze and hose, or by electricity, or by other means, when the assailant is advancing over it. The shaft or pit may **Fougasses.**

Fougasses.

be from 3 to 10′ deep. The depth in feet cubed and divided by 10, will give a suitable charge of powder in pounds. Thus, the charge for a 6′ fougass will be $\frac{6^3}{10} = \frac{216}{10} = 21 \cdot 6$ lbs.

A *shell fougass* is formed by dividing a box into two parts by a horizontal partition. Loaded shells are placed in the upper part; with the fuzes pointing downwards through holes in the partition. In the lower part is placed the charge of powder.

A *stone fougass* is formed by making an excavation in the form of the frustrum of a cone or pyramid, the axis of which is inclined at an angle of about 40° with the horizon. The depth of this excavation is usually about 6 feet. At the bottom a charge of powder (about 50 lbs. usually) is placed, properly secured, and with means provided for igniting it at any desired moment. Above this a wooden shield, from 3″ to 6″ thick, is placed perpendicularly to the axis of the fougass, and over this 3 or 4 cubic yards (about 4 or 5 tons) of stones of not less than half a pound each in weight are piled up. Such a fougass can be made by 12 men in three to four hours; and will disperse the stones over a circle of 30 to 40 yards radius, the centre being about 60 yards from the mouth of the fougass.

*Self-acting fougasses* are boxes of powder or loaded shells buried in the ground, so that they are just concealed by the earth; and fitted with some arrangement which will cause them to explode when a man steps upon them.

## DEFENCE OF A HOUSE.

Nature of protection afforded by a house.

A house may be prepared so as to place the defenders in a position of decided advantage in a contest with infantry, and of absolute safety against cavalry; but it cannot be made tenable against a sustained artillery attack. It must be remembered, however, that a well-directed musketry fire will prevent any battery remaining long in action within the effective range of rifles, and that consequently it will frequently be impossible for an assailant to maintain a concentrated artillery fire against an adequately garrisoned house.

Steps to be taken to prepare house for defence.

When a very short time only (one to three hours) is available for placing a house in a state of defence the following are the successive steps* which should generally be taken:—

1. Remove the inhabitants, and all easily combustible material; and provide water.

* Defence of Posts. Lieut.-Col. Schaw.

2. Barricade the doors and accessible windows so as to resist ingress and musketry fire. One door with a moveable barricade, or a window with a ladder, should be reserved for escape. Inaccessible windows should be masked so as to hide the defenders.

**Preparation for defence.**

3. Make loopholes.

4. Clear away cover in the vicinity as far as time and means allow; and while so doing arrange obstacles where possible.

If opportunity permits, after these first steps have been taken:—

5. Provide flank defence.

6. Improve the communication within the building by breaking through partition walls, &c.

7. Improve ventilation, to allow egress for the smoke from the men's rifles.

8. Store provisions and ammunition in safe places.

9. Prepare latrines.

10. If the house is liable to be attacked by artillery, shore up the floors of the upper rooms to prevent the possibility of a breach endangering the stability of upper floor; and spread 3″ of earth on the boards of the latter.

11. If the house be very large, and is to be defended *à l'outrance*, arrange for step by step defence :—by loopholing partition walls and upper floors; and by providing movable barricades to cover the retreat from one part of the building to another. It may occasionally also be advisable to remove the stairs and substitute ladders; but very frequently the imperfect communication entailed by taking such a step would outweigh the advantage gained.

12. In the case where a distant artillery attack is to be feared, provide shelter trenches, for the garrison to occupy, outside the building during the preliminary bombardment of the attackers.

## DETAILS OF DEFENCE.

### *Barricading Doors.*

**Barricading doors.**

Boxes, barrels, or cupboards filled with earth, or with bricks or stones, may be used to barricade doors, &c. Walls closing the entrances may be built up of paving stones, &c., or a stockade work may be constructed in front of the door or window to be shut up. Bearing in mind that 6″ or 8″ of any hard wood, double the thickness of soft fir timber, ½″ of iron, or a brick lengthways on, will keep out a rifle bullet, the materials at hand must be utilised as circumstances may suggest.

### *Providing Loopholes.*

Providing loopholes.

The loopholes will be made as described in the sections on the defence of walls. Those on the lower floor should be horizontal, to allow as much lateral range as possible to the grazing fire from the lower floor; those on the upper stories should, on the other hand, be made vertical to allow of as much depression as possible.

Distance of loopholes apart.

The minimum distance of the loopholes apart will depend on the thickness of the walls and their structural strength. The ordinary interval is about 4′, but this must be increased to 6′ in the case of thick walls loosely built; while it may be reduced to $2\frac{1}{2}'$ in good 9-inch brick walls. The height of the loopholes above the ground must be regulated as described in the sections on the defence of walls. A commanding line of fire for men in close order may often be obtained with very little labour by removing tiles or slates from just above the eaves of the roof, so that men may fire over the top of the wall.

### *Provision of Flank Defence.*

Flank defence.

Where the shape of the building is not such that its several parts mutually defend one another, flank defence may be supplied where necessary by building out "*tambours*," or constructing "*machicoulis galleries*."

*Tambours* are projections of stockade work, formed by planting firmly in the ground a row of contiguous bullet-proof timbers. A *machicoulis gallery* is a kind of balcony built outside a window, with musket-proof walls not more than 4′ in height, which may be loopholed; while openings are left in the floor through which a fire of musketry can be directed downwards to defend the foot of the wall below the window.

### *Provision of Ventilation.*

Ventilation.

Ventilation and light must be secured by leaving openings at the tops of windows when barricading them; by smoke escape holes through the walls under the ceilings in top stories; or, in buildings with only one floor, by removing tiles or slates, and breaking the ceiling away, if there be one.

## DEMOLITIONS.

### BUILDINGS.

Buildings having walls of moderate thickness may be demolished by placing a series of charges all along the outside of the walls, a trench being dug a few feet from the wall,

and the earth thrown up over the charges as tamping.* If the charges be sunk a little way into the wall, say about ⅓rd of its thickness, the effect produced by them will be much greater. Charges in lbs. = 2 or 3 times thickness of wall in feet and placed at intervals = twice the thickness of wall.

The best position for these mines would certainly be inside; but generally there would be difficulty in obtaining the required amount of earth there, and the wooden floors, &c. would impede the work.

## Demolishing Bridges.†

**Bridges with single arch.** The best mode of destroying a bridge of a single arch, or with short thick piers, is to explode a mine in the haunch.

**Bridges with high piers.** In a bridge with high piers, mines should be made in their bases, as the fall of one pier will bring down two arches. A series of small charges, lodged in the piers as close as possible to their bases, and fired simultaneously, seems preferable to a single large charge; as any slight imperfection in the masonry might permit action in that direction when a breach might be made without actually bringing down the pier.

**Bridges with short and thick piers.** Where the piers are broad and thick, it will be better to attack the arches than the piers.

**Iron girder bridges.** A bridge formed of large iron girders supported on masonry piers will be most easily demolished by attacking the piers; and it is probable that the girders in falling would be so buckled as to prevent their being used again.

Small iron girders can be levered off their bearings and broken by falling on rails, masonry, &c.; or they may be destroyed by a gun shot.

Wrought-iron girder bridges may be destroyed by means of large piles of sleepers, &c. lighted against the girders; which if made red hot will sink of their own weight.

**Suspension bridges.** Suspension bridges can be destroyed by uncovering and loosening one anchorage; or by blowing up one of the supporting piers of the cable.

**Destroying bridges by exploding charge on top.** When time and means will not permit of mines being made in the piers or arches, a large charge of powder may be exploded in a trench dug across the bridge over the key-stone; or, if there be time and labour, two deeper trenches may be dug across the bridge a few feet on either side of the key-stone.

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* Tamping is covering the charge over with earth or other matter, to develop the force of the explosion in the intended direction.

† Philipps on Demolition of Bridges.

The following formula* will give the charge necessary to destroy a bridge in this latter method:—

$C = \frac{3}{2} (LLR)^2 \times B.$

C = total charge of powder in lbs., placed either in a single charge or in a line of charges across the arch.

LLR (or line of least resistance) = distance in feet from charge to nearest point of inner surface of arch.

B = breadth of bridge in feet.

**Wooden bridges.** Wooden bridges were largely destroyed during the American war by burning. Kerosine oil was poured over the woodwork and set on fire.

To destroy wooden bridges with powder, the best method is to bore augur holes about 2″ in diameter in the supporting timber, at right angles to one another; place charges in these, and fire them simultaneously by electricity or Bickford's fuze.

**Gun cotton compared with gunpowder.** Compressed gun cotton fired with a detonating fuze is very useful for hasty demolitions. The effect produced is extremely violent, though local. Tamping is not of so much importance with gun cotton, and this is a considerable advantage in hasty demolitions. To produce an equivalent effect on masonry or brickwork the charge of gun cotton need only be in weight $\frac{2}{5}$ or $\frac{1}{2}$ that of gunpowder.

## Destruction of Railways.

**By blowing in tunnels, &c.** Bridges, tunnels, and deep cuttings are the most vulnerable points of railways. Bridges may be destroyed as described in preceding sections; tunnels or cuttings, by blowing in the retaining walls. It is better to blow in one long tunnel in several places than several tunnels only in one place.

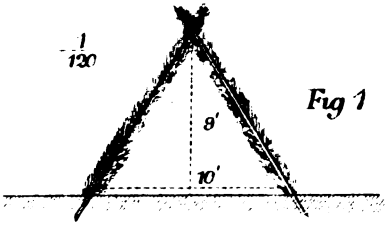
**By removing rails.** Where a line runs on the flat it is not so easily destroyed. The principal means will be tearing up the rails; curves should be selected as most difficult to repair. The usual tools for removing rails are heavy to carry, but a substitute for a wrench may be made out of a screw bolt. The usual process is to pull up the rails, collect the sleepers, and make a fire; and when the rails are hot, bend or twist them; the twist is much more effectual, as bent rails are easily straightened. Rails are easily twisted, when hot, by inserting the point of a pick in one of the bolt holes at either end and bearing in opposite directions.

* Deduced by Captain Schaw, R.E., from experiments made in the demolitions at Corfu.

# BIVOUAC OF BRANCHES OF TREES.

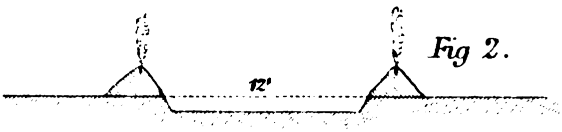
*Scale of Figs* $\frac{1}{120}$

Fig 1



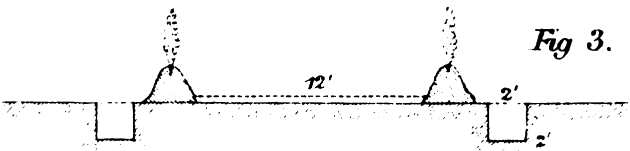

*Section of Bivouac*

Fig 2.



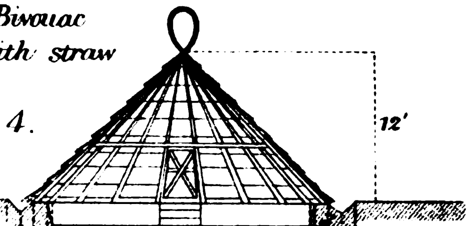

*Section of a better form of Bivouac*

Fig 3.



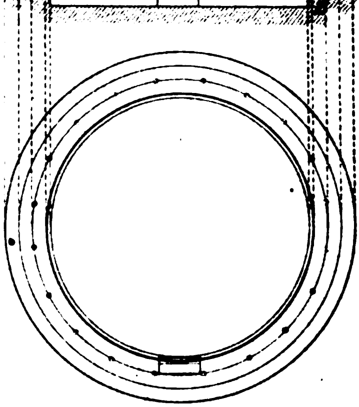

*Section of Bivouac thatched with straw*

Fig 4.




Plan

Fig 5.



Scale $\frac{1}{180}$

To face page 469.

Dancerfield Lith 22. Bedford St. Covent Garden

A method largely employed by the Americans, but which is applicable only to surface or lightly laid rails, was to draw up a detachment along a bit of line running along the top of an embankment. The ends, and if necessary the sleepers also, were loosened, and the detachment, standing close together outside, would lift altogether, and turn rail, sleepers, and all over; when the line could not be relaid without detaching rails and sleepers. *Removing rails.*

A line may be temporarily obstructed in an endless number of ways, *e.g.*, by running an engine off the line; by breaking one down; by leaving the fire in, blowing off steam, and taking out the safety valve; by fixing a projectile through the boiler, &c.

Rails may also be cut by exploding gun cotton against them; 8 ozs. will cut the heaviest rail.

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## ENCAMPMENTS AND BIVOUACS.

### CAMPS.

Whenever men remain under canvas in the same place for more than three days, tents should be struck every second day. All arms, straw and blankets should be removed and the ground should be swept clean with a broom or branches of trees; and be left exposed to the sun and wind. The tents should be roughly pitched in the intervals of the camp; with slack ropes and the fly loose to allow it to be well blown about. When repitched for the night the tents should again occupy exactly their old positions, as men invariably urinate at night round the tent and consequently the ground in the intervals becomes polluted. The flys of all tents should invariably be rolled up the first thing every morning. *Tents to be struck frequently.*

Trenches should be dug round the tents and a drain should connect these trenches to prevent water lodging in them. After the first rain, when the natural run of the water can be seen, these drains should be completed. *Trenches to carry off rain, &c.*

### BIVOUACS.

Fig. 1, Plate VII., and Fig. 1 and 2, Plate IX., show how branches of trees, canvas or straw may be utilised to afford some degree of shelter to men bivouacing. *Arrangements for affording shelter in bivouacs.*

Fig. 2, Plate VIII., shows a form of shelter which may be constructed if time and space are available. A circular trench, about 15′ in diameter, is dug, the turf being carefully cut and

employed to revet the interior slope; the earth excavated should be thrown against it and a bank, 2′ or 3′ high, formed. A fire may be lighted in the middle and the men will lie down, like the spokes of a wheel, with their feet to the fire.

Fig. 3, Plate VIII., shows a similar circular bivouac; to be used when the ground is damp or marshy.

Fig. 4 and 5, Plate VIII., shows a circular bivouac thatched with straw.

**Huts used by the Russians before Plevna.**

Fig. 3, 4, and 5, Plate IX., show the type of hut used by both Russians and Roumanians during the operations against Plevna. The conditions under which the huts were made were that wood was scarce, while the greatest warmth possible was desirable. For an officer's hut, Fig. 3, Plate IX., a square or oblong of ground is dug out to the depth of about 5′; and of the size that the constructor wishes his hut to be. On one side of this square the earth is left of a suitable height for a bed; and on the other of a convenient height for a table and shelf. At one end the earth is cut away so as to form a ramp up to the level of the ground outside; or else steps are built. At each end are placed uprights, connected by a cross beam; which supports one end of the rafters, the other resting on the ground. Over the rafters are placed branches, then maize straw and on the top of all the excavated earth.

The huts for the men, Fig. 5, Plate IX., were very similar to the officers. They were generally made to hold 20 men; a platform of earth being left on each side for the men to sleep on.

## Latrines.

**Latrines for one night.**

Latrines should always be constructed immediately men arrive upon the ground where they are to encamp or bivouac. For one night a small, shallow trench, some 15′ long and 1½′ deep, will suffice. This trench should be invariably filled in in the morning before the men march off.

**Latrines for a longer halt.**

If the halt be for a longer period a deeper and larger trench should be dug; the earth being used to form banks to serve as screens, and seats being arranged as shown in Fig. 1 and 2, Plate X. The trench should be made as narrow as possible and from 3′ to 4′ deep. Every day a couple of inches of earth should be thrown over the soil; and this, if carefully done, will prevent all smell. When the trench is filled up, a fresh one will be dug near it. Great care should be taken in selecting the site of the latrine so that no filtration from it may reach the water supply.

*Straw Lean to Shelter*

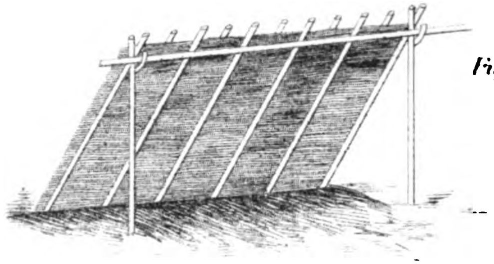


*Fig. 1*

*Canvass Lean to Shelter.*

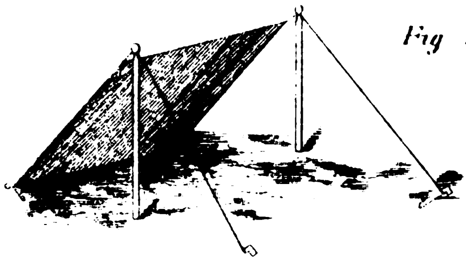


*Fig 2.*

*Officers Hut*
*Plan.*

*Fig 3.*


*Section*

*Fig. 4.*

*Plan of Hut for 20 Men.*

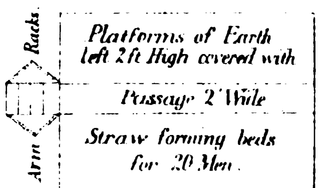



*Fig 5.*

*Scale of 10 5 0 10 20 30 Feet.*

*Fredk. Dangerfield, Lith. London.*

*To face page 470.*

Latrines.

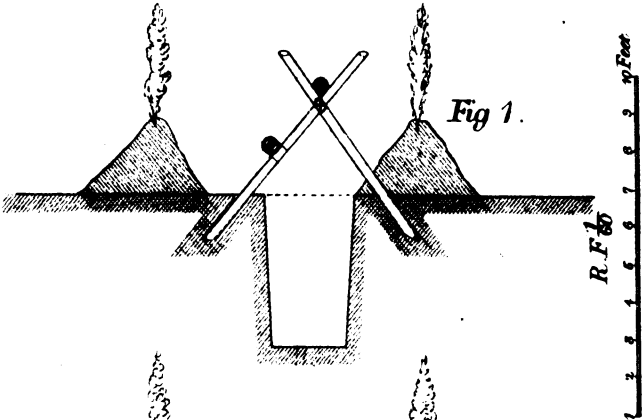



Fig 1.

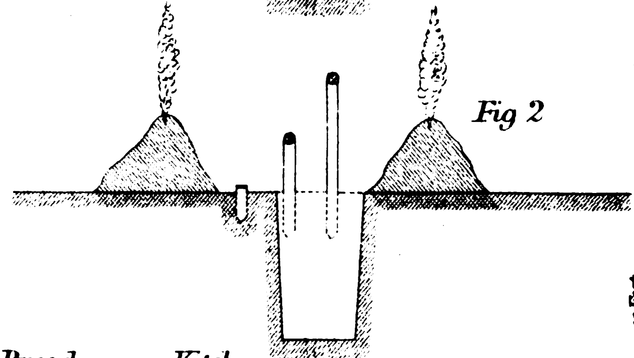
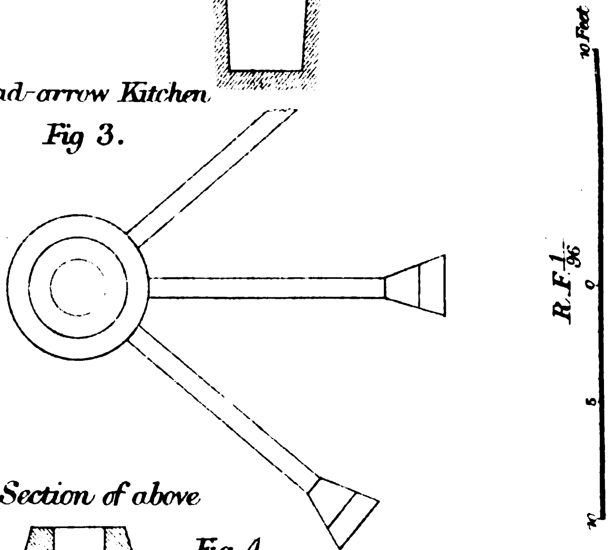


Fig 2

Broad-arrow Kitchen

Fig 3.

Plan




Section of above

Fig 4.

To face page 471.

Dangerfield Lith. 22 Bedford St. Covent Garden.

## Cooking.

The most simple and rapidly constructed kitchen consists of a trench, about 10′ long, 10″ wide, and 12″ deep, with a splay mouth pointing towards the wind.

**Broad Arrow kitchen.**

The Broad Arrow kitchen, Fig. 3 and 4, Plate X., is constructed as follows. A picket is driven into the ground to mark the centre of the chimney; and circles, respectively of 1′ and 3′ diameter, are traced to show the base of the chimney. The centre trench is then traced 10′ long and 10″ broad, with a splay mouth as shown in the plan; and the other two trenches are traced in a similar manner, one on either side, making an angle of about 40° with the central one.

One man excavates each trench, beginning from the bottom of the chimney and making it, as far as the latter extends, only 6″ wide and 12″ deep. When beyond the base of the chimney the width of each trench is increased to 10″; its depth also being gradually increased to 14″ at the mouth. Another man cuts out the bottom of the chimney to connect the three trenches and then begins to build the chimney; laying stones or sticks over the trenches at their ends to carry the base of the chimney and gradually building up the latter with sods cut by a fifth man. Great care must be taken in the construction of the chimney, all holes and interstices being plastered up with clay. The tops of the trenches are covered over with stones, hoop-iron or sticks plastered with clay; holes being moulded in the covering to receive the kettles and all interstices being closed with sods, &c. Five men should construct such a kitchen in about 3 hours. If clay be plentiful the inside of the trenches may be coated with it.

In bad weather, with high winds and rain the broad arrow kitchen will not burn satisfactorily. Under such circumstances it will be better to construct each kitchen of a single deep trench, with a chimney; the trench being 10′–15′ long, 2′ deep at the chimney end and 3′ deep at the mouth; this latter being made with a wide splay. In excavating the trench the latter for half its depth should be made 2′ wide; the lower half being only 1′ wide. The deeper part of the trench will then be covered over, like the trenches of the broad arrow kitchen, holes moulded in the covering for the bottoms of the kettles and the upper part of the trench round the kettles filled in again.

## NOTES for the PLATES.

R. F. above the scale stands for " Representative Fraction," and shows the proportion of the drawing to the natural size of the object.

Heights above the ground are indicated by a + sign.

Depths below the surface by a — sign.

The area of parapets in square feet is shown by figures in a square. Thus $\boxed{28}$ indicates that there are 28 sq. ft. in the section of the parapet shown.

The cubic content of a task is shown by figures in a circle. Thus (100) indicates that there are 100 cubic feet in each task. As a rule the men are assumed to be two paces (5′) apart.

The inclination of a slope is expressed by a fraction, of which the numerator shows the number of units in the perpendicular, the denominator the number of units in the base of a right angled triangle of which the slope is the hypothenuse.

# RANGE TABLES.

These range tables (with the exception of those for the 12·5 inch gun) are for projectiles without gas-checks.

Range tables for projectiles with gas-checks are in course of preparation, and will be issued when ready.

They will probably contain further information relative to the angles of descent, dangerous space, and probability of hitting at each range.

N.B.—Range tables must only be looked upon as approximate. In practice, where accuracy is required, a trial shot can alone be depended on.

## RANGE TABLE for 12·5-inch R.M.L. GUN of 38 Tons.

Battering Charge, 130 lb. $P^2$. with air space, 30 cubic inches per lb. of powder.

Projectile, Palliser, and Common Shell with gas-check Wt. 818 lbs.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | | Yards. | ° ′ | Secs. | |
| 200 | 0 18 | 0·46 | 1 | 2,690 | 4 30 | 6·71 | 16 |
| 280 | 0 25 | 0·64 | 1·5 | 2,760 | 4 39 | 6·92 | 16·5 |
| 370 | 0 32 | 0·85 | 2 | 2,840 | 4 48 | 7·12 | 17 |
| 460 | 0 40 | 1·06 | 2·5 | 2,910 | 4 57 | 7·33 | 17·5 |
| 550 | 0 48 | 1·27 | 3 | 2,980 | 5 6 | 7·54 | 18 |
| 640 | 0 56 | 1·48 | 3·5 | 3,060 | 5 14 | 7·75 | 18·5 |
| 730 | 1 4 | 1·70 | 4 | 3,130 | 5 22 | 7·96 | 19 |
| 810 | 1 12 | 1·87 | 4·5 | 3,210 | 5 30 | 8·17 | 19·5 |
| 890 | 1 20 | 2·07 | 5 | 3,280 | 5 39 | 8·37 | 20 |
| 980 | 1 28 | 2·28 | 5·5 | 3,360 | 5 48 | 8·57 | 20·5 |
| 1,060 | 1 34 | 2·47 | 6 | 3,430 | 5 57 | 8·78 | 21 |
| 1,140 | 1 42 | 2·66 | 6·5 | 3,500 | 6 6 | 8·98 | 21·5 |
| 1,220 | 1 50 | 2·86 | 7 | 3,580 | 6 15 | 9·19 | 22 |
| 1,310 | 1 58 | 3·07 | 7·5 | 3,650 | 6 24 | 9·40 | 22·5 |
| 1,400 | 2 6 | 3·29 | 8 | 3,720 | 6 34 | 9·61 | 23 |
| 1,480 | 2 14 | 3·49 | 8·5 | 3,800 | 6 44 | 9·82 | 23·5 |
| 1,560 | 2 23 | 3·68 | 9 | 3,880 | 6 54 | 10·03 | 24 |
| 1,640 | 2 32 | 3·89 | 9·5 | 3,950 | 7 4 | 10·24 | 24·5 |
| 1,730 | 2 41 | 4·10 | 10 | 4,020 | 7 14 | 10·46 | 25 |
| 1,810 | 2 50 | 4·30 | 10·5 | 4,100 | 7 24 | 10·68 | 25·5 |
| 1,890 | 2 59 | 4·51 | 11 | 4,180 | 7 34 | 10·90 | 26 |
| 1,980 | 3 8 | 4·73 | 11·5 | 4,250 | 7 44 | 11·12 | 26·5 |
| 2,060 | 3 17 | 4·96 | 12 | 4,320 | 7 54 | 11·34 | 27 |
| 2,140 | 3 26 | 5·18 | 12·5 | 4,400 | 8 4 | 11·55 | 27·5 |
| 2,220 | 3 35 | 5·40 | 13 | 4,480 | 8 14 | 11·77 | 28 |
| 2,300 | 3 44 | 5·62 | 13·5 | 4,560 | 8 24 | 12·00 | 28·5 |
| 2,380 | 3 53 | 5·84 | 14 | 4,640 | 8 34 | 12·22 | 29 |
| 2,450 | 4 2 | 6·05 | 14·5 | 4,710 | 8 44 | 12·45 | 29·5 |
| 2,530 | 4 12 | 6·26 | 15 | 4,790 | 8 54 | 12·68 | 30 |
| 2,610 | 4 21 | 6·47 | 15·5 | | | | |

**Range Table for 12·5-inch R.M.L. Gun of 38 Tons.**

**Charge, 100 lb. P². Powder.**

**Projectile, Common or Shrapnel Shell with gas-check.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 180 | 0 15 | | 1 | 2,700 | 4 41 | | 16 |
| 280 | 0 25 | | 1·5 | 2,770 | 4 50 | | 16·5 |
| 370 | 0 34 | | 2 | 2,840 | 4 58 | | 17 |
| 460 | 0 43 | | 2·5 | 2,910 | 5 6 | | 17·5 |
| 550 | 0 52 | | 3 | 2,990 | 5 16 | | 18 |
| 640 | 1 1 | | 3·5 | 3,060 | 5 24 | | 18·5 |
| 730 | 1 10 | | 4 | 3,100 | 5 33 | | 19 |
| 820 | 1 19 | | 4·5 | 3,200 | 5 42 | | 19·5 |
| 910 | 1 28 | | 5 | 3,270 | 5 50 | | 20 |
| 1,000 | 1 38 | | 5·5 | 3,340 | 5 58 | | 20·5 |
| 1,080 | 1 46 | | 6 | 3,400 | 6 6 | | 21 |
| 1,160 | 1 54 | | 6·5 | 3,470 | 6 15 | | 21·5 |
| 1,250 | 2 4 | | 7 | 3,540 | 6 24 | | 22 |
| 1,340 | 2 14 | | 7·5 | 3,600 | 6 33 | | 22·5 |
| 1,420 | 2 22 | | 8 | 3,660 | 6 41 | | 23 |
| 1,510 | 2 32 | | 8·5 | 3,730 | 6 50 | | 23·5 |
| 1,590 | 2 40 | | 9 | 3,790 | 6 58 | | 24 |
| 1,670 | 2 48 | | 9·5 | 3,850 | 7 6 | | 24·5 |
| 1,750 | 2 57 | | 10 | 3,920 | 7 15 | | 25 |
| 1,830 | 3 5 | | 10·5 | 3,980 | 7 24 | | 25·5 |
| 1,920 | 3 14 | | 11 | 4,040 | 7 33 | | 26 |
| 2,000 | 3 22 | | 11·5 | 4,100 | 7 42 | | 26·5 |
| 2,080 | 3 31 | | 12 | 4,160 | 7 51 | | 27 |
| 2,160 | 3 40 | | 12·5 | 4,220 | 8 0 | | 27·5 |
| 2,240 | 3 48 | | 13 | 4,290 | 8 9 | | 28 |
| 2,320 | 3 57 | | 13·5 | 4,350 | 8 18 | | 28·5 |
| 2,400 | 4 6 | | 14 | 4,410 | 8 27 | | 29 |
| 2,470 | 4 15 | | 14·5 | 4,460 | 8 36 | | 29·5 |
| 2,550 | 4 24 | | 15 | 4,520 | 8 45 | | 30 |
| 2,630 | 4 33 | | 15·5 | | | | |

RANGE TABLE for 12-INCH R.M.L. GUN of 35 TONS.

Battering Charge, 110 lbs. P. Powder.

Projectile, Palliser Shell, without gas-check. Weight, 700 lbs.

| Distance of Object. | Elevation. | Time of Flight. | Fuze Scale. | Distance of Object. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | | Yards. | ° ′ | Secs. | |
| 100 | 0 10 | 0·25 | | 2,500 | 4 16 | 6·04 | |
| 200 | 0 19 | 0·47 | | 2,600 | 4 28 | 6·32 | |
| 300 | 0 28 | 0·69 | | 2,700 | 4 40 | 6·60 | |
| 400 | 0 37 | 0·91 | | 2,800 | 4 52 | 6·88 | |
| 500 | 0 46 | 1·14 | | 2,900 | 5 4 | 7·17 | |
| 600 | 0 55 | 1·37 | | 3,000 | 5 16 | 7·46 | |
| 700 | 1 4 | 1·60 | | 3,100 | 5 28 | 7·75 | |
| 800 | 1 14 | 1·83 | | 3,200 | 5 40 | 8·04 | |
| 900 | 1 24 | 2·06 | | 3,300 | 5 52 | 8·33 | |
| 1,000 | 1 34 | 2·29 | | 3,400 | 6 4 | 8·62 | |
| 1,100 | 1 44 | 2·52 | | 3,500 | 6 16 | 8·91 | |
| 1,200 | 1 54 | 2·76 | | 3,600 | 6 28 | 9·20 | |
| 1,300 | 2 4 | 3·00 | | 3,700 | 6 40 | 9·49 | |
| 1,400 | 2 15 | 3·24 | | 3,800 | 6 52 | 9·78 | |
| 1,500 | 2 26 | 3·48 | | 3,900 | 7 4 | 10·07 | |
| 1,600 | 2 37 | 3·72 | | 4,000 | 7 17 | 10·36 | |
| 1,700 | 2 48 | 3·96 | | 4,100 | 7 30 | 10·66 | |
| 1,800 | 2 59 | 4·20 | | 4,200 | 7 43 | 10·96 | |
| 1,900 | 3 10 | 4·44 | | 4,300 | 7 56 | 11·26 | |
| 2,000 | 3 21 | 4·69 | | 4,400 | 8 9 | 11·56 | |
| 2,100 | 3 32 | 4·95 | | 4,500 | 8 22 | 11·86 | |
| 2,200 | 3 43 | 5·21 | | 4,600 | 8 35 | 12·16 | |
| 2,300 | 3 54 | 5·48 | | 4,700 | 8 48 | 12·46 | |
| 2,400 | 4 5 | 5·76 | | 4,800 | 9 1 | 12·76 | |

**Range Table for 12-inch R.M.L. Gun of 35 Tons.**

**Charge, 85 lb. P. Powder.**

**Projectile, Common Shell, without gas-check. Weight 617 lbs.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 200 | 0 19 | | 1 | 2,640 | 5 4 | | 16 |
| 300 | 0 29 | | 1·5 | 2,710 | 5 13 | | 16·5 |
| 390 | 0 38 | | 2 | 2,780 | 5 23 | | 17 |
| 490 | 0 48 | | 2·5 | 2,850 | 5 33 | | 17·5 |
| 580 | 0 57 | | 3 | 2,910 | 5 41 | | 18 |
| 680 | 1 7 | | 3·5 | 2,980 | 5 51 | | 18·5 |
| 770 | 1 17 | | 4 | 3,040 | 6 0 | | 19 |
| 860 | 1 27 | | 4·5 | 3,110 | 6 9 | | 19·5 |
| 950 | 1 37 | | 5 | 3,170 | 6 18 | | 20 |
| 1,040 | 1 47 | | 5·5 | 3,230 | 6 27 | | 20·5 |
| 1,120 | 1 56 | | 6 | 3,290 | 6 36 | | 21 |
| 1,210 | 2 6 | | 6·5 | 3,350 | 6 45 | | 21·5 |
| 1,290 | 2 15 | | 7 | 3,410 | 6 54 | | 22 |
| 1,380 | 2 24 | | 7·5 | 3,470 | 7 3 | | 22·5 |
| 1,460 | 2 34 | | 8 | 3,530 | 7 12 | | 23 |
| 1,540 | 2 43 | | 8·5 | 3,590 | 7 21 | | 23·5 |
| 1,620 | 2 53 | | 9 | 3,650 | 7 30 | | 24 |
| 1,700 | 3 3 | | 9·5 | 3,710 | 7 39 | | 24·5 |
| 1,780 | 3 12 | | 10 | 3,770 | 7 48 | | 25 |
| 1,850 | 3 21 | | 10·5 | 3,830 | 7 57 | | 25·5 |
| 1,930 | 3 31 | | 11 | 3,880 | 8 5 | | 26 |
| 2,000 | 3 40 | | 11·5 | 3,940 | 8 14 | | 26·5 |
| 2,080 | 3 50 | | 12 | 4,000 | 8 24 | | 27 |
| 2,150 | 3 59 | | 12·5 | 4,060 | 8 33 | | 27·5 |
| 2,220 | 4 8 | | 13 | 4,120 | 8 43 | | 28 |
| 2,300 | 4 19 | | 13·5 | 4,180 | 8 52 | | 28·5 |
| 2,370 | 4 28 | | 14 | 4,230 | 9 0 | | 29 |
| 2,440 | 4 37 | | 14·5 | 4,280 | 9 8 | | 29·5 |
| 2,510 | 4 46 | | 15 | 4,330 | 9 16 | | 30 |
| 2,580 | 4 55 | | 15·5 | | | | |

Note.—This range table is not applicable to Palliser projectiles, as their weight is 700 lbs.

**Range Table for 12-inch R.M.L. Gun of 25 Tons**

**Battering Charge, 85 lb. P. Powder.**

**Projectile, Common Shell, without gas-check. Weight 497 lbs.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 180 | 0 9 | | 1 | 2,710 | 4 57 | | 16 |
| 280 | 0 16 | | 1·5 | 2,790 | 5 7 | | 16·5 |
| 370 | 0 23 | | 2 | 2,860 | 5 17 | | 17 |
| 470 | 0 32 | | 2·5 | 2,940 | 5 28 | | 17·5 |
| 500 | 0 41 | | 3 | 3,010 | 5 38 | | 18 |
| 650 | 0 50 | | 3·5 | 3,090 | 5 49 | | 18·5 |
| 740 | 1 0 | | 4 | 3,160 | 5 59 | | 19 |
| 830 | 1 10 | | 4·5 | 3,230 | 6 9 | | 19·5 |
| 910 | 1 19 | | 5 | 3,300 | 6 19 | | 20 |
| 1,000 | 1 29 | | 5·5 | 3,370 | 6 29 | | 20·5 |
| 1,080 | 1 38 | | 6 | 3,440 | 6 40 | | 21 |
| 1,170 | 1 47 | | 6·5 | 3,510 | 6 50 | | 21·5 |
| 1,250 | 1 56 | | 7 | 3,580 | 7 0 | | 22 |
| 1,340 | 2 6 | | 7·5 | 3,650 | 7 10 | | 22·5 |
| 1,420 | 2 16 | | 8 | 3,710 | 7 20 | | 23 |
| 1,510 | 2 27 | | 8·5 | 3,790 | 7 33 | | 23·5 |
| 1,590 | 2 36 | | 9 | 3,850 | 7 43 | | 24 |
| 1,680 | 2 47 | | 9·5 | 3,910 | 7 53 | | 24·5 |
| 1,760 | 2 57 | | 10 | 3,980 | 8 5 | | 25 |
| 1,840 | 3 6 | | 10·5 | 4,040 | 8 15 | | 25·5 |
| 1,920 | 3 16 | | 11 | 4,110 | 8 27 | | 26 |
| 2,000 | 3 26 | | 11·5 | 4,170 | 8 38 | | 26·5 |
| 2,080 | 3 36 | | 12 | 4,230 | 8 48 | | 27 |
| 2,160 | 3 46 | | 12·5 | 4,300 | 9 0 | | 27·5 |
| 2,240 | 3 56 | | 13 | 4,360 | 9 10 | | 28 |
| 2,320 | 4 6 | | 13·5 | 4,420 | 9 20 | | 28·5 |
| 2,400 | 4 17 | | 14 | 4,480 | 9 30 | | 29 |
| 2,480 | 4 27 | | 14·5 | 4,540 | 9 40 | | 29·5 |
| 2,560 | 4 37 | | 15 | 4,600 | 9 51 | | 30 |
| 2,640 | 4 47 | | 15·5 | | | | |

Note.—These range tables are not applicable to

**Range Table for 12-inch R.M.L. Gun of 25 Tons.**

**Charge, 55 lb. P. Powder**

**Projectile, Common Shell, without gas-check. Weight 497 lbs.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 160 | 0 19 | | 1 | 2,560 | 5 54 | | 16 |
| 240 | 0 28 | | 1·5 | 2,630 | 6 5 | | 16·5 |
| 320 | 0 38 | | 2 | 2,710 | 6 18 | | 17 |
| 410 | 0 49 | | 2·5 | 2,780 | 6 30 | | 17·5 |
| 490 | 0 59 | | 3 | 2,860 | 6 43 | | 18 |
| 570 | 1 8 | | 3·5 | 2,930 | 6 55 | | 18·5 |
| 650 | 1 19 | | 4 | 3,000 | 7 7 | | 19 |
| 740 | 1 31 | | 4·5 | 3,080 | 7 20 | | 19·5 |
| 820 | 1 41 | | 5 | 3,150 | 7 32 | | 20 |
| 900 | 1 52 | | 5·5 | 3,220 | 7 44 | | 20·5 |
| 980 | 2 2 | | 6 | 3,290 | 7 57 | | 21 |
| 1,070 | 2 14 | | 6·5 | 3,370 | 8 11 | | 21·5 |
| 1,150 | 2 25 | | 7 | 3,440 | 8 24 | | 22 |
| 1,230 | 2 36 | | 7·5 | 3,510 | 8 37 | | 22·5 |
| 1,310 | 2 47 | | 8 | 3,580 | 8 50 | | 23 |
| 1,390 | 2 58 | | 8·5 | 3,650 | 9 3 | | 23·5 |
| 1,470 | 3 9 | | 9 | 3,720 | 9 16 | | 24 |
| 1,550 | 3 21 | | 9·5 | 3,790 | 9 30 | | 24·5 |
| 1,630 | 3 32 | | 10 | 3,860 | 9 44 | | 25 |
| 1,710 | 3 43 | | 10·5 | 3,930 | 9 58 | | 25·5 |
| 1,790 | 3 55 | | 11 | 4,000 | 10 12 | | 26 |
| 1,870 | 4 7 | | 11·5 | 4,070 | 10 26 | | 26·5 |
| 1,940 | 4 18 | | 12 | 4,130 | 10 40 | | 27 |
| 2,020 | 4 30 | | 12·5 | 4,200 | 10 54 | | 27·5 |
| 2,100 | 4 42 | | 13 | 4,270 | 11 8 | | 28 |
| 2,180 | 4 54 | | 13·5 | 4,330 | 11 22 | | 28·5 |
| 2,250 | 5 5 | | 14 | 4,400 | 11 36 | | 29 |
| 2,330 | 5 17 | | 14·5 | 4,460 | 11 48 | | 29·5 |
| 2,410 | 5 30 | | 15 | 4,530 | 12 2 | | 30 |
| 2,480 | 5 51 | | 15·5 | | | | |

Palliser projectiles, as their weight is 600 lbs.

## RANGE TABLE for 11-INCH R.M.L. GUN of 25 Tons.

### Battering Charge, 85 lbs. P. Powder.

### Projectile, Palliser Shot and Shell, and Common Shell, without gas-checks.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | | Yards. | ° ′ | Secs. | |
| 100 | 0 12 | 0·24 | | 2,500 | 4 43 | 6·61 | |
| 200 | 0 22 | 0·49 | | 2,600 | 4 56 | 6·91 | |
| 300 | 0 32 | 0·74 | | 2,700 | 5 10 | 7·21 | |
| 400 | 0 42 | 0·99 | | 2,800 | 5 24 | 7·51 | |
| 500 | 0 52 | 1·24 | | 2,900 | 5 38 | 7·81 | |
| 600 | 1 2 | 1·49 | | 3,000 | 5 52 | 8·11 | |
| 700 | 1 12 | 1·74 | | 3,100 | 6 6 | 8·41 | |
| 800 | 1 22 | 1·99 | | 3,200 | 6 20 | 8·72 | |
| 900 | 1 32 | 2·24 | | 3,300 | 6 34 | 9·03 | |
| 1,000 | 1 43 | 2·49 | | 3,400 | 6 48 | 9·34 | |
| 1,100 | 1 54 | 2·74 | | 3,500 | 7 3 | 9·65 | |
| 1,200 | 2 5 | 2·99 | | 3,600 | 7 18 | 9·96 | |
| 1,300 | 2 16 | 3·25 | | 3,700 | 7 33 | 10·28 | |
| 1,400 | 2 27 | 3·51 | | 3,800 | 7 48 | 10·60 | |
| 1,500 | 2 38 | 3·78 | | 3,900 | 8 3 | 10·92 | |
| 1,600 | 2 50 | 4·05 | | 4,000 | 8 19 | 11·24 | |
| 1,700 | 3 2 | 4·32 | | 4,100 | 8 35 | 11·57 | |
| 1,800 | 3 14 | 4·60 | | 4,200 | 8 51 | 11·90 | |
| 1,900 | 3 26 | 4·88 | | 4,300 | 9 7 | 12·23 | |
| 2,000 | 3 38 | 5·16 | | 4,400 | 9 23 | 12·56 | |
| 2,100 | 3 51 | 5·44 | | 4,500 | 9 40 | 12·89 | |
| 2,200 | 4 4 | 5·72 | | 4,600 | 9 57 | 13·22 | |
| 2,300 | 4 17 | 6·01 | | 4,700 | 10 14 | 13·55 | |
| 2,400 | 4 30 | 6·31 | | 4,800 | 10 31 | 13·88 | |

**RANGE TABLE for 11-INCH R.M.L. GUN of 25 TONS.**

**Charge, 60 lb. P. Powder.**

**Projectile, Common or Shrapnel Shell, without gas-checks.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 150 | 0 19 | | 1 | 2,400 | 5 47 | | 16 |
| 230 | 0 30 | | 1·5 | 2,470 | 5 58 | | 16·5 |
| 300 | 0 39 | | 2 | 2,540 | 6 9 | | 17 |
| 380 | 0 50 | | 2·5 | 2,620 | 6 22 | | 17·5 |
| 460 | 1 1 | | 3 | 2,690 | 6 33 | | 18 |
| 540 | 1 12 | | 3·5 | 2,760 | 6 44 | | 18·5 |
| 610 | 1 22 | | 4 | 2,830 | 6 55 | | 19 |
| 690 | 1 33 | | 4·5 | 2,910 | 7 8 | | 19·5 |
| 760 | 1 43 | | 5 | 2,980 | 7 19 | | 20 |
| 840 | 1 54 | | 5·5 | 3,050 | 7 31 | | 20·5 |
| 910 | 2 4 | | 6 | 3,120 | 7 42 | | 21 |
| 990 | 2 15 | | 6·5 | 3,200 | 7 56 | | 21·5 |
| 1,060 | 2 25 | | 7 | 3,270 | 8 7 | | 22 |
| 1,140 | 2 36 | | 7·5 | 3,340 | 8 19 | | 22·5 |
| 1,210 | 2 46 | | 8 | 3,410 | 8 31 | | 23 |
| 1,290 | 2 58 | | 8·5 | 3,490 | 8 45 | | 23·5 |
| 1,360 | 3 9 | | 9 | 3,560 | 8 57 | | 24 |
| 1,430 | 3 19 | | 9·5 | 3,630 | 9 9 | | 24·5 |
| 1,510 | 3 31 | | 10 | 3,700 | 9 21 | | 25 |
| 1,580 | 3 42 | | 10·5 | 3,780 | 9 34 | | 25·5 |
| 1,660 | 3 54 | | 11 | 3,850 | 9 47 | | 26 |
| 1,730 | 4 4 | | 11·5 | 3,920 | 9 59 | | 26·5 |
| 1,810 | 4 16 | | 12 | 3,990 | 10 12 | | 27 |
| 1,880 | 4 27 | | 12·5 | 4,070 | 10 26 | | 27·5 |
| 1,960 | 4 39 | | 13 | 4,140 | 10 39 | | 28 |
| 2,030 | 4 49 | | 13·5 | 4,210 | 10 51 | | 28·5 |
| 2,110 | 5 1 | | 14 | 4,280 | 11 4 | | 29 |
| 2,180 | 5 12 | | 14·5 | 4,360 | 11 16 | | 29·5 |
| 2,250 | 5 23 | | 15 | 4,420 | 11 29 | | 30 |
| 2,330 | 5 35 | | 15·5 | | | | |

## Range Table for 10-inch R.M.L. Gun of 18 Tons.

### Battering Charge, 70 lb. P. Powder.

### Projectile, Common Shell, without gas-checks.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 170 | 0 15 | | 1 | 2,570 | 4 42 | | 16 |
| 260 | 0 23 | | 1·5 | 2,640 | 4 52 | | 16·5 |
| 340 | 0 31 | | 2 | 2,710 | 5 2 | | 17 |
| 430 | 0 39 | | 2·5 | 2,780 | 5 12 | | 17·5 |
| 510 | 0 47 | | 3 | 2,850 | 5 22 | | 18 |
| 600 | 0 55 | | 3·5 | 2,920 | 5 32 | | 18·5 |
| 680 | 1 3 | | 4 | 2,990 | 5 42 | | 19 |
| 770 | 1 12 | | 4·5 | 3,060 | 5 52 | | 19·5 |
| 850 | 1 21 | | 5 | 3,130 | 6 2 | | 20 |
| 940 | 1 30 | | 5·5 | 3,200 | 6 12 | | 20·5 |
| 1,020 | 1 39 | | 6 | 3,260 | 6 22 | | 21 |
| 1,110 | 1 48 | | 6·5 | 3,330 | 6 32 | | 21·5 |
| 1,190 | 1 57 | | 7 | 3,400 | 6 42 | | 22 |
| 1,270 | 2 6 | | 7·5 | 3,460 | 6 51 | | 22·5 |
| 1,350 | 2 15 | | 8 | 3,530 | 7 1 | | 23 |
| 1,430 | 2 24 | | 8·5 | 3,590 | 7 10 | | 23·5 |
| 1,510 | 2 33 | | 9 | 3,660 | 7 21 | | 24 |
| 1,590 | 2 42 | | 9·5 | 3,720 | 7 31 | | 24·5 |
| 1,670 | 2 52 | | 10 | 3,780 | 7 41 | | 25 |
| 1,750 | 3 2 | | 10·5 | 3,850 | 7 52 | | 25·5 |
| 1,820 | 3 11 | | 11 | 3,910 | 8 1 | | 26 |
| 1,900 | 3 20 | | 11·5 | 3,970 | 8 11 | | 26·5 |
| 1,970 | 3 29 | | 12 | 4,030 | 8 20 | | 27 |
| 2,050 | 3 38 | | 12·5 | 4,090 | 8 30 | | 27·5 |
| 2,120 | 3 47 | | 13 | 4,150 | 8 40 | | 28 |
| 2,200 | 3 56 | | 13·5 | 4,210 | 8 50 | | 28·5 |
| 2,270 | 4 5 | | 14 | 4,270 | 9 0 | | 29 |
| 2,350 | 4 14 | | 14·5 | 4,330 | 9 10 | | 29·5 |
| 2,420 | 4 23 | | 15 | 4,380 | 9 18 | | 30 |
| 2,500 | 4 32 | | 15·5 | | | | |

## Range Table for 10-inch R.M.L. Gun of 18 Tons.

### Charge, 44 lb. P. Powder.

### Projectile, Common Shell, without gas-check.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 160 | 0 19 | | 1 | 2,330 | 5 36 | | 16 |
| 240 | 0 28 | | 1·5 | 2,400 | 5 47 | | 16·5 |
| 320 | 0 38 | | 2 | 2,460 | 5 58 | | 17 |
| 400 | 0 48 | | 2·5 | 2,530 | 6 10 | | 17·5 |
| 480 | 0 58 | | 3 | 2,590 | 6 21 | | 18 |
| 560 | 1 8 | | 3·5 | 2,660 | 6 34 | | 18·5 |
| 630 | 1 18 | | 4 | 2,720 | 6 46 | | 19 |
| 710 | 1 28 | | 4·5 | 2,790 | 6 59 | | 19·5 |
| 780 | 1 38 | | 5 | 2,850 | 7 11 | | 20 |
| 860 | 1 49 | | 5·5 | 2,910 | 7 23 | | 20·5 |
| 930 | 1 59 | | 6 | 2,970 | 7 35 | | 21 |
| 1,000 | 2 9 | | 6·5 | 3,030 | 7 47 | | 21·5 |
| 1,080 | 2 20 | | 7 | 3,090 | 7 59 | | 22 |
| 1,150 | 2 30 | | 7·5 | 3,150 | 8 11 | | 22·5 |
| 1,220 | 2 40 | | 8 | 3,210 | 8 23 | | 23 |
| 1,300 | 2 51 | | 8·5 | 3,270 | 8 35 | | 23·5 |
| 1,370 | 3 1 | | 9 | 3,330 | 8 48 | | 24 |
| 1,440 | 3 12 | | 9·5 | 3,390 | 9 0 | | 24·5 |
| 1,510 | 3 22 | | 10 | 3,440 | 9 12 | | 25 |
| 1,580 | 3 33 | | 10·5 | 3,500 | 9 25 | | 25·5 |
| 1,650 | 3 43 | | 11 | 3,560 | 9 38 | | 26 |
| 1,720 | 3 54 | | 11·5 | 3,620 | 9 51 | | 26·5 |
| 1,790 | 4 5 | | 12 | 3,670 | 10 2 | | 27 |
| 1,860 | 4 16 | | 12·5 | 3,730 | 10 15 | | 27·5 |
| 1,930 | 4 27 | | 13 | 3,790 | 10 29 | | 28 |
| 2,000 | 4 39 | | 13·5 | 3,840 | 10 42 | | 28·5 |
| 2,070 | 4 50 | | 14 | 3,900 | 10 56 | | 29 |
| 2,140 | 5 2 | | 14·5 | 3,950 | 11 8 | | 29·5 |
| 2,200 | 5 13 | | 15 | 4,010 | 11 23 | | 30 |
| 2,270 | 5 25 | | 15·5 | | | | |

RANGE TABLE for 9-INCH R.M.L. GUN of 12 Tons.

Battering Charge, 50 lbs. P. Powder.

Projectile, Palliser or Common Shell, without gas-checks.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 180 | 0 11 | | 1 | 2,700 | 4 53 | | 16 |
| 280 | 0 18 | | 1·5 | 2,770 | 5 3 | | 16·5 |
| 370 | 0 25 | | 2 | 2,840 | 5 13 | | 17 |
| 460 | 0 33 | | 2·5 | 2,900 | 5 23 | | 17·5 |
| 550 | 0 41 | | 3 | 2,970 | 5 33 | | 18 |
| 640 | 0 49 | | 3·5 | 3,030 | 5 43 | | 18·5 |
| 730 | 0 57 | | 4 | 3,100 | 5 53 | | 19 |
| 820 | 1 5 | | 4·5 | 3,160 | 6 2 | | 19·5 |
| 910 | 1 14 | | 5 | 3,230 | 6 12 | | 20 |
| 1,000 | 1 23 | | 5·5 | 3,290 | 6 22 | | 20·5 |
| 1,090 | 1 32 | | 6 | 3,360 | 6 32 | | 21 |
| 1,180 | 1 41 | | 6·5 | 3,420 | 6 42 | | 21·5 |
| 1,270 | 1 50 | | 7 | 3,490 | 6 52 | | 22 |
| 1,350 | 1 59 | | 7·5 | 3,550 | 7 2 | | 22·5 |
| 1,440 | 2 9 | | 8 | 3,620 | 7 12 | | 23 |
| 1,520 | 2 19 | | 8·5 | 3,680 | 7 23 | | 23·5 |
| 1,610 | 2 29 | | 9 | 3,750 | 7 34 | | 24 |
| 1,690 | 2 39 | | 9·5 | 3,810 | 7 45 | | 24·5 |
| 1,780 | 2 49 | | 10 | 3,880 | 7 56 | | 25 |
| 1,860 | 2 59 | | 10·5 | 3,940 | 8 7 | | 25·5 |
| 1,940 | 3 9 | | 11 | 4,010 | 8 18 | | 26 |
| 2,030 | 3 20 | | 11·5 | 4,070 | 8 29 | | 26·5 |
| 2,100 | 3 30 | | 12 | 4,140 | 8 40 | | 27 |
| 2,180 | 3 40 | | 12·5 | 4,200 | 8 51 | | 27·5 |
| 2,260 | 3 51 | | 13 | 4,260 | 9 2 | | 28 |
| 2,330 | 4 1 | | 13·5 | 4,330 | 9 13 | | 28·5 |
| 2,410 | 4 12 | | 14 | 4,390 | 9 24 | | 29 |
| 2,480 | 4 22 | | 14·5 | 4,450 | 9 35 | | 29·5 |
| 2,560 | 4 33 | | 15 | 4,510 | 9 46 | | 30 |
| 2,630 | 4 43 | | 15·5 | | | | |

## Range Table for 9-inch R.M.L. Gun of 12 Tons.

### Charge, 30 lbs. R.L.G. Powder.

### Projectile, Common Shell, without gas-check.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 160 | 0 18 | | 1 | 2,580 | 5 57 | | 16 |
| 250 | 0 28 | | 1·5 | 2,650 | 6 8 | | 16·5 |
| 330 | 0 38 | | 2 | 2,720 | 6 19 | | 17 |
| 420 | 0 49 | | 2·5 | 2,790 | 6 30 | | 17·5 |
| 500 | 1 0 | | 3 | 2,860 | 6 40 | | 18 |
| 580 | 1 11 | | 3·5 | 2,930 | 6 51 | | 18·5 |
| 670 | 1 22 | | 4 | 3,000 | 7 2 | | 19 |
| 750 | 1 33 | | 4·5 | 3,070 | 7 13 | | 19·5 |
| 830 | 1 44 | | 5 | 3,142 | 7 24 | | 20 |
| 920 | 1 55 | | 5·5 | 3,210 | 7 35 | | 20·5 |
| 1,000 | 2 6 | | 6 | 3,280 | 7 47 | | 21 |
| 1,080 | 2 17 | | 6·5 | 3,340 | 7 57 | | 21·5 |
| 1,170 | 2 28 | | 7 | 3,410 | 8 9 | | 22 |
| 1,250 | 2 40 | | 7·5 | 3,470 | 8 20 | | 22·5 |
| 1,330 | 2 52 | | 8 | 3,540 | 8 31 | | 23 |
| 1,420 | 3 4 | | 8·5 | 3,600 | 8 42 | | 23·5 |
| 1,500 | 3 16 | | 9 | 3,670 | 8 54 | | 24 |
| 1,580 | 3 27 | | 9·5 | 3,740 | 9 5 | | 24·5 |
| 1,660 | 3 39 | | 10 | 3,800 | 9 16 | | 25 |
| 1,740 | 3 51 | | 10·5 | 3,870 | 9 28 | | 25·5 |
| 1,820 | 4 3 | | 11 | 3,930 | 9 39 | | 26 |
| 1,900 | 4 15 | | 11·5 | 3,990 | 9 50 | | 26·5 |
| 1,980 | 4 27 | | 12 | 4,040 | 10 1 | | 27 |
| 2,060 | 4 39 | | 12·5 | 4,100 | 10 11 | | 27·5 |
| 2,130 | 4 51 | | 13 | 4,150 | 10 21 | | 28 |
| 2,210 | 5 2 | | 13·5 | 4,210 | 10 30 | | 28·5 |
| 2,290 | 5 13 | | 14· | 4,260 | 10 39 | | 29 |
| 2,360 | 5 24 | | 14·5 | 4,310 | 10 48 | | 29·5 |
| 2,430 | 5 35 | | 15 | 4,360 | 10 57 | | 30 |
| 2,510 | 5 46 | | 15·5 | | | | |

### Range Table for 8-inch R.M.L. Gun of 9 Tons.
### Battering Charge, 35 lb. P. Powder.
### Projectile, Palliser or Common Shell.

| Range. | Eleva-tion. | Time of Flight. | Fuze Scale. | Range. | Eleva-tion. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 180 | 0 11 | | 1 | 2,610 | 4 53 | | 16 |
| 270 | 0 19 | | 1·5 | 2,680 | 5 3 | | 16·5 |
| 360 | 0 27 | | 2 | 2,740 | 5 13 | | 17 |
| 450 | 0 35 | | 2·5 | 2,810 | 5 23 | | 17·5 |
| 540 | 0 43 | | 3 | 2,870 | 5 33 | | 18 |
| 630 | 0 51 | | 3·5 | 2,940 | 5 44 | | 18·5 |
| 710 | 1 0 | | 4 | 3,000 | 5 54 | | 19 |
| 800 | 1 9 | | 4·5 | 3,070 | 6 4 | | 19·5 |
| 880 | 1 18 | | 5 | 3,130 | 6 14 | | 20 |
| 970 | 1 27 | | 5·5 | 3,200 | 6 25 | | 20·5 |
| 1,050 | 1 36 | | 6 | 3,260 | 6 36 | | 21 |
| 1,140 | 1 45 | | 6·5 | 3,320 | 6 47 | | 21·5 |
| 1,220 | 1 54 | | 7 | 3,390 | 6 57 | | 22 |
| 1,310 | 2 3 | | 7·5 | 3,460 | 7 7 | | 22·5 |
| 1,390 | 2 12 | | 8 | 3,520 | 7 17 | | 23 |
| 1,470 | 2 21 | | 8·5 | 3,590 | 7 28 | | 23·5 |
| 1,550 | 2 30 | | 9 | 3,650 | 7 38 | | 24 |
| 1,630 | 2 39 | | 9·5 | 3,720 | 7 49 | | 24·5 |
| 1,710 | 2 48 | | 10 | 3,780 | 7 59 | | 25 |
| 1,790 | 2 57 | | 10·5 | 3,850 | 8 9 | | 25·5 |
| 1,870 | 3 7 | | 11 | 3,910 | 8 19 | | 26 |
| 1,950 | 3 17 | | 11·5 | 3,980 | 8 30 | | 26·5 |
| 2,030 | 3 28 | | 12 | 4,040 | 8 41 | | 27 |
| 2,100 | 3 39 | | 12·5 | 4,110 | 8 52 | | 27·5 |
| 2,180 | 3 50 | | 13 | 4,170 | 9 2 | | 28 |
| 2,250 | 4 1 | | 13·5 | 4,230 | 9 13 | | 28·5 |
| 2,330 | 4 12 | | 14 | 4,290 | 9 24 | | 29 |
| 2,400 | 4 22 | | 14·5 | 4,360 | 9 35 | | 29·5 |
| 2,470 | 4 32 | | 15 | 4,420 | 9 45 | | 30 |
| 2,540 | 4 43 | | 15·5 | | | | |

# RANGE TABLE for 8-INCH R.M.L. GUN of 9 Tons.

Charge, 20 lb. R.L.G. Powder.

Projectile, Common Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 170 | 0 17 | | 1 | 2,380 | 5 28 | | 16 |
| 250 | 0 26 | | 1·5 | 2,450 | 5 40 | | 16·5 |
| 330 | 0 35 | | 2 | 2,520 | 5 52 | | 17 |
| 410 | 0 44 | | 2·5 | 2,590 | 6 4 | | 17·5 |
| 480 | 0 53 | | 3 | 2,650 | 6 16 | | 18 |
| 560 | 1 2 | | 3·5 | 2,720 | 6 28 | | 18·5 |
| 640 | 1 11 | | 4 | 2,780 | 6 40 | | 19 |
| 720 | 1 21 | | 4·5 | 2,840 | 6 52 | | 19·5 |
| 790 | 1 31 | | 5 | 2,910 | 7 4 | | 20 |
| 870 | 1 41 | | 5·5 | 2,970 | 7 16 | | 20·5 |
| 940 | 1 51 | | 6 | 3,030 | 7 28 | | 21 |
| 1,020 | 2 1 | | 6·5 | 3,100 | 7 40 | | 21·5 |
| 1,090 | 2 11 | | 7 | 3,160 | 7 51 | | 22 |
| 1,170 | 2 21 | | 7·5 | 3,220 | 8 3 | | 22·5 |
| 1,240 | 2 31 | | 8 | 3,280 | 8 15 | | 23 |
| 1,320 | 2 42 | | 8·5 | 3,340 | 8 26 | | 23·5 |
| 1,390 | 2 53 | | 9 | 3,390 | 8 37 | | 24 |
| 1,470 | 3 4 | | 9·5 | 3,450 | 8 49 | | 24·5 |
| 1,540 | 3 15 | | 10 | 3,510 | 9 1 | | 25 |
| 1,620 | 3 26 | | 10·5 | 3,580 | 9 13 | | 25·5 |
| 1,690 | 3 37 | | 11 | 3,630 | 9 24 | | 26 |
| 1,760 | 3 48 | | 11·5 | 3,690 | 9 36 | | 26·5 |
| 1,830 | 3 59 | | 12 | 3,740 | 9 47 | | 27 |
| 1,900 | 4 10 | | 12·5 | 3,800 | 9 59 | | 27·5 |
| 1,970 | 4 21 | | 13 | 3,860 | 10 11 | | 28 |
| 2,040 | 4 32 | | 13·5 | 3,920 | 10 23 | | 28·5 |
| 2,110 | 4 43 | | 14 | 3,970 | 10 35 | | 29 |
| 2,180 | 4 54 | | 14·5 | 4,030 | 10 47 | | 29·5 |
| 2,250 | 5 5 | | 15 | 4,080 | 10 59 | | 30 |
| 2,320 | 5 16 | | 15·5 | | | | |

# Range Table for 7-inch R.M.L. Gun of 6½ Tons.

## Battering Charge, 30 lb. P. Powder.

## Projectile, Palliser or Common Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 190 | 0 9 | | 1 | 2,600 | 3 58 | | 16 |
| 280 | 0 15 | | 1·5 | 2,670 | 4 7 | | 16·5 |
| 380 | 0 22 | | 2 | 2,740 | 4 16 | | 17 |
| 470 | 0 29 | | 2·5 | 2,810 | 4 25 | | 17·5 |
| 560 | 0 36 | | 3 | 2,880 | 4 34 | | 18 |
| 650 | 0 43 | | 3·5 | 2,950 | 4 43 | | 18·5 |
| 740 | 0 50 | | 4 | 3,010 | 4 52 | | 19 |
| 830 | 0 57 | | 4·5 | 3,080 | 5 7 | | 19·5 |
| 920 | 1 4 | | 5 | 3,150 | 5 16 | | 20 |
| 1,000 | 1 11 | | 5·5 | 3,210 | 5 25 | | 20·5 |
| 1,090 | 1 18 | | 6 | 3,280 | 5 34 | | 21 |
| 1,170 | 1 25 | | 6·5 | 3,340 | 5 43 | | 21·5 |
| 1,260 | 1 32 | | 7 | 3,410 | 5 52 | | 22 |
| 1,340 | 1 39 | | 7·5 | 3,470 | 6 1 | | 22·5 |
| 1,420 | 1 46 | | 8 | 3,530 | 6 10 | | 23 |
| 1,500 | 1 54 | | 8·5 | 3,600 | 6 21 | | 23·5 |
| 1,580 | 2 2 | | 9 | 3,660 | 6 30 | | 24 |
| 1,660 | 2 10 | | 9·5 | 3,720 | 6 40 | | 24·5 |
| 1,730 | 2 18 | | 10 | 3,780 | 6 50 | | 25 |
| 1,810 | 2 26 | | 10·5 | 3,840 | 7 0 | | 25·5 |
| 1,880 | 2 34 | | 11 | 3,900 | 7 10 | | 26 |
| 1,960 | 2 42 | | 11·5 | 3,960 | 7 20 | | 26·5 |
| 2,030 | 2 50 | | 12 | 4,020 | 7 30 | | 27 |
| 2,110 | 2 58 | | 12·5 | 4,080 | 7 40 | | 27·5 |
| 2,180 | 3 6 | | 13 | 4,140 | 7 50 | | 28 |
| 2,250 | 3 14 | | 13·5 | 4,200 | 8 0 | | 28·5 |
| 2,320 | 3 22 | | 14 | 4,260 | 8 10 | | 29 |
| 2,390 | 3 31 | | 14·5 | 4,310 | 8 20 | | 29·5 |
| 2,460 | 3 40 | | 15 | 4,370 | 8 30 | | 30 |
| 2,530 | 3 49 | | 15·5 | | | | |

RANGE TABLE for 7-INCH R.M.L. GUN of 6½ Tons.

Charge, 14 lbs. R.L.G. Powder.

Projectile, Common Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 170 | 0 16 | | 1 | 2,330 | 5 21 | | 16 |
| 250 | 0 24 | | 1·5 | 2,390 | 5 32 | | 16·5 |
| 330 | 0 33 | | 2 | 2,450 | 5 43 | | 17 |
| 410 | 0 42 | | 2·5 | 2,510 | 5 54 | | 17·5 |
| 480 | 0 51 | | 3 | 2,570 | 6 5 | | 18 |
| 560 | 1 0 | | 3·5 | 2,630 | 6 15 | | 18·5 |
| 630 | 1 10 | | 4 | 2,680 | 6 27 | | 19 |
| 710 | 1 20 | | 4·5 | 2,740 | 6 39 | | 19·5 |
| 790 | 1 30 | | 5 | 2,800 | 6 49 | | 20 |
| 870 | 1 40 | | 5·5 | 2,850 | 7 0 | | 20·5 |
| 940 | 1 50 | | 6 | 2,910 | 7 11 | | 21 |
| 1,010 | 2 0 | | 6·5 | 2,960 | 7 22 | | 21·5 |
| 1,090 | 2 10 | | 7 | 3,020 | 7 33 | | 22 |
| 1,170 | 2 20 | | 7·5 | 3,070 | 7 43 | | 22·5 |
| 1,230 | 2 30 | | 8 | 3,120 | 7 53 | | 23 |
| 1,310 | 2 40 | | 8·5 | 3,180 | 8 3 | | 23·5 |
| 1,380 | 2 50 | | 9 | 3,230 | 8 13 | | 24 |
| 1,450 | 3 0 | | 9·5 | 3,280 | 8 23 | | 24·5 |
| 1,530 | 3 10 | | 10 | 3,330 | 8 33 | | 25 |
| 1,600 | 3 20 | | 10·5 | 3,380 | 8 43 | | 25·5 |
| 1,660 | 3 31 | | 11 | 3,420 | 8 53 | | 26 |
| 1,730 | 3 42 | | 11·5 | 3,470 | 9 3 | | 26·5 |
| 1,800 | 3 53 | | 12 | 3,520 | 9 12 | | 27 |
| 1,870 | 4 4 | | 12·5 | 3,560 | 9 21 | | 27·5 |
| 1,930 | 4 15 | | 13 | 3,600 | 9 30 | | 28 |
| 2,000 | 4 26 | | 13·5 | 3,640 | 9 39 | | 28·5 |
| 2,070 | 4 37 | | 14 | 3,690 | 9 48 | | 29 |
| 2,130 | 4 48 | | 14·5 | 3,740 | 9 57 | | 29·5 |
| 2,200 | 4 59 | | 15 | 3,770 | 10 5 | | 30 |
| 2,270 | 5 10 | | 15·5 | | | | |

RANGE TABLE for 7-INCH R.M.L. GUN of 6½ Tons.
Charge, 14 lbs. R.L.G. Powder.
Projectile, Double Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | Ins. | Yards. | | | |
| 100 | 0 14 | 0·30 | | 1,700 | | | |
| 155 | — | — | ·1 | 1,800 | | | |
| 200 | 0 28 | 0·60 | | 1,900 | | | |
| 300 | 0 42 | 0·90 | | 2,000 | | | |
| 315 | — | — | ·2 | 2,100 | | | |
| 400 | 0 56 | 1·20 | | 2,200 | | | |
| 470 | — | — | ·3 | 2,300 | | | |
| 500 | 1 10 | 1·50 | | 2,400 | | | |
| 600 | 1 25 | 1·80 | | 2,500 | | | |
| 630 | — | — | ·4 | 2,600 | | | |
| 700 | 1 41 | 2·15 | | 2,700 | | | |
| 785 | | — | ·5 | 2,800 | | | |
| 800 | 1 57 | 2·45 | | 2,900 | | | |
| 900 | 2 14 | 2·75 | | 3,000 | | | |
| 940 | — | — | ·6 | 3,100 | | | |
| 1,000 | 2 31 | 3·10 | | 3,200 | | | |
| 1,080 | — | — | ·7 | 3,300 | | | |
| 1,100 | 2 50 | 3·40 | | 3,400 | | | |
| 1,200 | 3 9 | 3·75 | | 3,500 | | | |
| 1,235 | — | — | ·8 | 3,600 | | | |
| 1,300 | | | | 3,700 | | | |
| 1,400 | | | | 3,800 | | | |
| 1,500 | | | | 3,900 | | | |
| 1,600 | | | | 4,000 | | | |

## Range Table for 7-inch R.M.L. Gun of 4½ Tons.

### Charge, 22 lb. P. Powder.

| Projectile—Palliser, Shrapnel, or Common Shell. | | | | | | | | Double Shell, without Gas Check. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Time of Flight. | Elevation. | Fuze Scale. |
| Yards. | ° ′ | ″ | | Yards. | ° ′ | ″ | | Yards. | ° ′ | ″ | |
| 140 | — | 0·36 | 1·0 | 2,110 | 4 21 | 5·93 | 14·5 | 100 | — | 0·27 | |
| 200 | 0 1 | 0·54 | 1·5 | 2,190 | 4 33 | 6·16 | 15·0 | 200 | — | 0·54 | |
| 260 | 0 9 | 0·72 | 2·0 | 2,260 | 4 45 | 6·39 | 15·5 | 300 | 0 12 | 0·82 | |
| 330 | 0 15 | 0·90 | 2·5 | 2,330 | 4 57 | 6·63 | 16·0 | 400 | 0 26 | 1·10 | |
| 400 | 0 22 | 1·09 | 3·0 | 2,410 | 5 8 | 6·87 | 16·5 | 500 | 0 40 | 1·39 | |
| 470 | 0 31 | 1·28 | 3·5 | 2,490 | 5 20 | 7·11 | 17·0 | 600 | 0 54 | 1·69 | |
| 550 | 0 40 | 1·47 | 4·0 | 2,570 | 5 32 | 7·35 | 17·5 | 700 | 1 9 | 1·99 | |
| 630 | 0 49 | 1·66 | 4·5 | 2,640 | 5 44 | 7·60 | 18·0 | 800 | 1 24 | 2·30 | |
| 700 | 0 58 | 1·85 | 5·0 | 2,720 | 5 56 | 7·85 | 18·5 | 900 | 1 39 | 2·61 | |
| 780 | 1 8 | 2·05 | 5·5 | 2,800 | 6 8 | 8·10 | 19·0 | 1,000 | 1 55 | 2·92 | |
| 850 | 1 18 | 2·25 | 6·0 | 2,870 | 6 20 | 8·35 | 19·5 | 1,100 | 2 11 | 3·23 | |
| 920 | 1 28 | 2·45 | 6·5 | 2,940 | 6 32 | 8·60 | 20·0 | 1,200 | 2 27 | 3·54 | |
| 990 | 1 38 | 2·65 | 7·0 | 3,020 | 6 44 | 8·85 | 20·5 | 1,300 | 2 44 | 3·85 | |
| 1,060 | 1 48 | 2·85 | 7·5 | 3,090 | 6 56 | 9·11 | 21·0 | 1,400 | 3 1 | 4·16 | |
| 1,130 | 1 58 | 3·05 | 8·0 | 3,170 | 7 8 | 9·38 | 21·5 | 1,500 | 3 18 | 4·47 | |
| 1,200 | 2 8 | 3·26 | 8·5 | 3,250 | 7 20 | 9·65 | 22·0 | 1,600 | 3 35 | 4·78 | |
| 1,280 | 2 19 | 3·47 | 9·0 | 3,320 | 7 32 | 9·92 | 22·5 | 1,700 | 3 53 | 5·10 | |
| 1,350 | 2 30 | 3·68 | 9·5 | 3,400 | 7 44 | 10·20 | 23·0 | 1,800 | 4 11 | 5·42 | |
| 1,430 | 2 41 | 3·90 | 10·0 | 3,480 | 7 57 | 10·48 | 23·5 | 1,900 | 6 29 | 5·74 | |
| 1,510 | 2 52 | 4·12 | 10·5 | 3,550 | 8 10 | 10·76 | 24·0 | 2,000 | 4 47 | 6·06 | |
| 1,590 | 3 3 | 4·34 | 11·0 | 3,630 | 8 23 | 11·05 | 24·5 | 2,100 | 5 5 | 6·38 | |
| 1,660 | 3 14 | 4·56 | 11·5 | 3,710 | 8 36 | 11·35 | 25·0 | 2,200 | 5 24 | 6·70 | |
| 1,730 | 3 25 | 4·78 | 12·0 | 3,790 | 8 49 | 11·65 | 25·5 | 2,300 | 5 43 | 7·02 | |
| 1,810 | 3 36 | 5·01 | 12·5 | 3,870 | 9 03 | 11·95 | 26·0 | 2,400 | 6 02 | 7·35 | |
| 1,890 | 3 47 | 5·24 | 13·0 | 3,950 | 9 17 | 12·26 | 26·5 | 2,500 | 6 21 | 7·68 | |
| 1,960 | 3 58 | 5·47 | 13·5 | | | | | | | | |
| 2,040 | 4 09 | 5·70 | 14·0 | | | | | | | | |

## RANGE TABLE for 64-PR. R.M.L. GUN of 64 Cwt.

Charge, 10 lbs. R.L.G. Powder.

Projectile, Common Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 160 | 0 12 | | 1 | 2,580 | 5 21 | | 16 |
| 250 | 0 19 | | 1·5 | 2,660 | 5 38 | | 16·5 |
| 330 | 0 27 | | 2 | 2,730 | 5 45 | | 17 |
| 420 | 0 35 | | 2·5 | 2,800 | 5 58 | | 17·5 |
| 500 | 0 43 | | 3 | 2,870 | 6 11 | | 18 |
| 590 | 0 51 | | 3·5 | 2,950 | 6 24 | | 18·5 |
| 670 | 0 59 | | 4 | 3,020 | 6 37 | | 19 |
| 760 | 1 7 | | 4·5 | 3,090 | 6 50 | | 19·5 |
| 840 | 1 16 | | 5 | 3,160 | 7 4 | | 20 |
| 930 | 1 25 | | 5·5 | 3,230 | 7 18 | | 20·5 |
| 1,010 | 1 34 | | 6 | 3,300 | 7 32 | | 21 |
| 1,090 | 1 43 | | 6·5 | 3,370 | 7 46 | | 21·5 |
| 1,170 | 1 52 | | 7 | 3,440 | 8 0 | | 22 |
| 1,260 | 2 2 | | 7·5 | 3,510 | 8 14 | | 22·5 |
| 1,340 | 2 13 | | 8 | 3,580 | 8 28 | | 23 |
| 1,420 | 2 24 | | 8·5 | 3,650 | 8 42 | | 23·5 |
| 1,500 | 2 35 | | 9 | 3,710 | 8 56 | | 24 |
| 1,590 | 2 46 | | 9·5 | 3,780 | 9 10 | | 24·5 |
| 1,670 | 2 57 | | 10 | 3,850 | 9 24 | | 25 |
| 1,750 | 3 9 | | 10·5 | 3,920 | 9 38 | | 25·5 |
| 1,830 | 3 21 | | 11 | 3,980 | 9 52 | | 26 |
| 1,910 | 3 33 | | 11·5 | 4,050 | 10 6 | | 26·5 |
| 1,990 | 3 45 | | 12 | 4,120 | 10 20 | | 27 |
| 2,060 | 3 57 | | 12·5 | 4,180 | 10 34 | | 27·5 |
| 2,140 | 4 9 | | 13 | 4,250 | 10 49 | | 28 |
| 2,210 | 4 21 | | 13·5 | 4,310 | 11 4 | | 28·5 |
| 2,290 | 4 33 | | 14 | 4,380 | 11 19 | | 29 |
| 2,360 | 4 45 | | 14·5 | 4,440 | 11 34 | | 29·5 |
| 2,440 | 4 57 | | 15 | 4,510 | 11 50 | | 30 |
| 2,510 | 5 0 | | 15·5 | | | | |

**RANGE TABLE for 64-PR. R.M.L. GUN of 64 Cwt. and 64-PR. R.M.L. CONVERTED GUNS of 71 and 58 Cwts.**

**Charge, 8 lbs. R.L.G. Powder.**

**Projectile, Common Shell.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 170 | 0 17 | | 1 | 2,350 | 5 34 | | 16 |
| 260 | 0 26 | | 1·5 | 2,410 | 5 46 | | 16·5 |
| 350 | 0 36 | | 2 | 2,470 | 5 48 | | 17 |
| 430 | 0 46 | | 2·5 | 2,530 | 6 10 | | 17·5 |
| 510 | 0 56 | | 3 | 2,590 | 6 22 | | 18 |
| 590 | 1 6 | | 3·5 | 2,650 | 6 34 | | 18·5 |
| 670 | 1 16 | | 4 | 2,710 | 6 46 | | 19 |
| 750 | 1 26 | | 4·5 | 2,770 | 6 58 | | 19·5 |
| 830 | 1 36 | | 5 | 2,830 | 7 11 | | 20 |
| 910 | 1 46 | | 5·5 | 2,890 | 7 24 | | 20·5 |
| 980 | 1 56 | | 6 | 2,940 | 7 37 | | 21 |
| 1,060 | 2 6 | | 6·5 | 3,000 | 7 50 | | 21·5 |
| 1,140 | 2 16 | | 7 | 3,060 | 8 3 | | 22 |
| 1,210 | 2 26 | | 7·5 | 3,110 | 8 16 | | 22·5 |
| 1,290 | 2 37 | | 8 | 3,170 | 8 29 | | 23 |
| 1,360 | 2 48 | | 8·5 | 3,220 | 8 42 | | 23·5 |
| 1,430 | 2 59 | | 9 | 3,280 | 8 55 | | 24 |
| 1,500 | 3 10 | | 9·5 | 3,330 | 9 8 | | 24·5 |
| 1,570 | 3 21 | | 10 | 3,380 | 9 21 | | 25 |
| 1,640 | 3 32 | | 10·5 | 3,440 | 9 34 | | 25·5 |
| 1,710 | 3 43 | | 11 | 3,490 | 9 47 | | 26 |
| 1,780 | 3 54 | | 11·5 | 3,540 | 10 0 | | 26·5 |
| 1,850 | 4 5 | | 12 | 3,590 | 10 13 | | 27 |
| 1,910 | 4 16 | | 12·5 | 3,640 | 10 26 | | 27·5 |
| 1,980 | 4 27 | | 13 | 3,690 | 10 39 | | 28 |
| 2,040 | 4 38 | | 13·5 | 3,740 | 10 52 | | 28·5 |
| 2,110 | 4 49 | | 14 | 3,790 | 11 5 | | 29 |
| 2,170 | 5 0 | | 14·5 | 3,840 | 11 18 | | 29·5 |
| 2,230 | 5 11 | | 15 | 3,890 | 11 30 | | 30 |
| 2,290 | 5 22 | | 15·5 | | | | |

## Range Table for 64-Pr. R.M.L. Gun of 64 Cwt. and 64-Pr. R.M.L. Converted Guns of 71 Cwt.

Charge, 6 lbs. R.L.G. Powder.

Projectile, Common Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | Ins. | Yards. | ° ′ | Secs. | Ins. |
| 100 | 0 13 | 0·36 | 0·08 | 2,100 | 5 53 | 7·18 | 1·65 |
| 200 | 0 26 | 0·69 | 0·16 | 2,200 | 6 15 | 7·56 | 1·74 |
| 300 | 0 39 | 1·03 | 0·24 | 2,300 | 6 37 | 7·95 | 1·83 |
| 400 | 9 52 | 1·37 | 0·32 | 2,400 | 7 0 | 8·34 | 1·92 |
| 500 | 1 6 | 1·71 | 0·39 | 2,500 | 7 23 | 8·74 | 2·01 |
| 600 | 1 20 | 2·05 | 0·47 | 2,600 | 7 48 | 9·14 | 2·10 |
| 700 | 1 35 | 2·39 | 0·55 | 2,700 | 8 13 | 9·54 | 2·19 |
| 800 | 1 50 | 2·73 | 0·63 | 2,800 | 8 39 | 9·95 | 2·29 |
| 900 | 2 6 | 3·07 | 0·71 | 2,900 | 9 5 | 10·37 | 2·39 |
| 1,000 | 2 22 | 3·41 | 0·78 | 3,000 | 9 31 | 10·79 | 2·48 |
| 1,100 | 2 39 | 3·75 | 0·86 | 3,100 | 9 57 | 11·22 | 2·58 |
| 1,200 | 2 56 | 4·09 | 0·94 | 3,200 | 10 24 | 11·66 | 2·68 |
| 1,300 | 3 14 | 4·43 | 1·02 | 3,300 | 10 52 | 12·10 | 2·78 |
| 1,400 | 3 32 | 4·77 | 1·10 | 3,400 | 11 21 | 12·54 | 2·88 |
| 1,500 | 3 50 | 5·11 | 1·18 | 3,500 | 11 51 | 12·98 | 2·99 |
| 1,600 | 4 9 | 5·45 | 1·25 | 3,600 | | | |
| 1,700 | 4 28 | 5·79 | 1·33 | 3,700 | | | |
| 1,800 | 4 48 | 6·13 | 1·41 | 3,800 | | | |
| 1,900 | 5 9 | 6·47 | 1·49 | 3,900 | | | |
| 2,000 | 5 31 | 6·82 | 1·57 | 4,000 | | | |

## Range Table for 40-Pr. R.B.L. Gun of 32 Cwt.

### Charge, 5 lbs. R.L.G. Powder

### Projectile, Common Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | Ins. | Yards. | ° ′ | Secs. | Ins. |
| 100 | 0 10 | 0·35 | 0·05 | 1,600 | 3 57 | 4·95 | 1·00 |
| 200 | 0 21 | 0·65 | 0·10 | 1,700 | 4 15 | 5·30 | 1·05 |
| 300 | 0 33 | 0·95 | 0·15 | 1,800 | 4 33 | 5·60 | 1·10 |
| 400 | 0 45 | 1·25 | 0·20 | 1,900 | 4 51 | 5·95 | 1·20 |
| 500 | 0 58 | 1·55 | 0·25 | 2,000 | 5 9 | 6·50 | 1·25 |
| 600 | 1 12 | 1·85 | 0·35 | 2,100 | 5 27 | 6·60 | 1·35 |
| 700 | 1 27 | 2·15 | 0·40 | 2,200 | 5 45 | 7·00 | 1·40 |
| 800 | 1 42 | 2·45 | 0·50 | 2,300 | 6 4 | 7·35 | 1·45 |
| 900 | 1 57 | 2·75 | 0·55 | 2,400 | 6 24 | 7·70 | 1·55 |
| 1,000 | 2 13 | 3·05 | 0·60 | 2,500 | 6 44 | 8·05 | 1·60 |
| 1,100 | 2 29 | 3·35 | 0·65 | 2,600 | 7 5 | 8·45 | 1·70 |
| 1,200 | 2 46 | 3·70 | 0·75 | 2,700 | 7 27 | 8·80 | 1·75 |
| 1,300 | 3 3 | 4·00 | 0·80 | 2,800 | 7 49 | 9·20 | 1·85 |
| 1,400 | 3 21 | 4·30 | 0·85 | 2,900 | | | |
| 1,500 | 3 39 | 4·65 | 0·95 | 3,000 | | | |

## Range Table for 20-pr. R.B.L. Gun of 13 and 15 Cwt.

### Charge, 2 lbs. 8 oz. R.L.G. Powder.

### Projectile, Shot or Shell.

| Range. | Elevation. | Time of Flight. | Length of Wood Time Fuze. | Length of E Time Fuze. | Range. | Elevation. | Time of Flight. | Length of Wood Time Fuze. | Length of E Time Fuze. |
|---|---|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | Ins. | Ins. | Yards. | ° ′ | Secs. | Ins. | Ins. |
| 100 | 0 7 | — | 0·05 | 0·15 | 1,600 | 4 54 | 5·74 | 1·20 | 2·85 |
| 200 | 0 20 | — | 0·10 | 0·30 | 1,700 | 5 16 | 6·15 | 1·30 | 3·05 |
| 300 | 0 33 | 1·06 | 0·20 | 0·50 | 1,800 | 5 38 | 6·56 | 1·35 | 3·25 |
| 400 | 0 47 | 1·40 | 0·25 | 0·65 | 1,900 | 6 1 | 6·98 | 1·40 | 3·45 |
| 500 | 1 4 | 1·75 | 0·35 | 0·85 | 2,000 | 6 24 | 7·38 | 1·50 | 3·65 |
| 600 | 1 22 | 2·10 | 0·40 | 1·00 | 2,100 | 6 48 | 7·80 | 1·60 | 3·80 |
| 700 | 1 41 | 2·44 | 0·50 | 1·20 | 2,200 | 7 12 | 8·20 | 1·70 | 4·00 |
| 800 | 2 1 | 2·79 | 0·55 | 1·35 | 2,300 | 7 36 | 8·62 | 1·80 | |
| 900 | 2 21 | 3·16 | 0·65 | 1·55 | 2,400 | 8 1 | 9·06 | 1·90 | |
| 1,000 | 2 42 | 3·52 | 0·75 | 1·75 | 2,500 | 8 28 | 9·50 | 2·00 | |
| 1,100 | 3 4 | 3·88 | 0·80 | 1·90 | 2,600 | 8 56 | 9·93 | | |
| 1,200 | 3 26 | 4·29 | 0·90 | 2·10 | 2,700 | 9 25 | 10·37 | | |
| 1,300 | 3 48 | 4·60 | 0·95 | 2·30 | 2,800 | 9 53 | 10·80 | | |
| 1,400 | 4 10 | 4·98 | 1·05 | 2·50 | 2,900 | 10 22 | 11·26 | | |
| 1,500 | 4 32 | 5·36 | 1·15 | 2·70 | 3,000 | 10 51 | 11·75 | | |

## RANGE TABLE for 9-PR. R.M.L. GUN of 8 and 6 Cwt.
### Charge, 1 lb. 12 oz. R.L.G. Powder.
### Projectile, Shrapnel Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 200 | 0 6 | | 1 | 2,600 | 6 59 | | 16 |
| 320 | 0 15 | | 1·5 | 2,660 | 7 16 | | 16·5 |
| 420 | 0 28 | | 2 | 2,730 | 7 33 | | 17 |
| 520 | 0 41 | | 2·5 | 2,790 | 7 50 | | 17·5 |
| 620 | 0 54 | | 3 | 2,860 | 8 7 | | 18 |
| 720 | 1 7 | | 3·5 | 2,920 | 8 24 | | 18·5 |
| 820 | 1 20 | | 4 | 2,980 | 8 42 | | 19 |
| 910 | 1 32 | | 4·5 | 3,040 | 9 0 | | 19·5 |
| 1,000 | 1 44 | | 5 | 3,100 | 9 18 | | 20 |
| 1,090 | 1 56 | | 5·5 | 3,160 | 9 36 | | 20·5 |
| 1,180 | 2 9 | | 6 | 3,220 | 9 55 | | 21 |
| 1,260 | 2 22 | | 6·5 | 3,280 | 10 14 | | 21·5 |
| 1,340 | 2 35 | | 7 | 3,340 | 10 33 | | 22 |
| 1,420 | 2 47 | | 7·5 | 3,400 | 10 53 | | 22·5 |
| 1,490 | 3 1 | | 8 | 3,450 | 11 13 | | 23 |
| 1,570 | 3 15 | | 8·5 | 3,510 | 11 33 | | 23·5 |
| 1,640 | 3 29 | | 9 | 3,560 | 11 53 | | 24 |
| 1,710 | 3 43 | | 9·5 | 3,620 | 12 12 | | 24·5 |
| 1,780 | 3 57 | | 10 | 3,670 | 12 31 | | 25 |
| 1,850 | 4 11 | | 10·5 | 3,780 | 12 50 | | 25·5 |
| 1,920 | 4 25 | | 11 | 3,780 | 13 9 | | 26 |
| 1,990 | 4 39 | | 11·5 | 3,840 | 13 28 | | 26·5 |
| 2,060 | 4 54 | | 12 | 3,900 | 13 47 | | 27 |
| 2,130 | 5 9 | | 12·5 | 3,950 | 14 6 | | 27·5 |
| 2,200 | 5 24 | | 13 | 4,000 | 14 24 | | 28 |
| 2,270 | 5 39 | | 13·5 | 4,050 | 14 42 | | 28·5 |
| 2,340 | 5 54 | | 14 | 4,100 | 15 0 | | 29 |
| 2,400 | 6 10 | | 14·5 | 4,150 | 15 17 | | 29·5 |
| 2,470 | 6 26 | | 15 | 4,200 | 15 33 | | 30 |
| 2,530 | 6 42 | | 15·5 | | | | |

N.B.—Common shell being lighter than shrapnel, ranges about 100 yards farther with the same elevation.

## RANGE TABLE for 9-PR. R.M.L. GUN of 6 Cwt. S.S.

**Charge, 1 lb. 8 oz.**

**Projectile, Common Shell.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 190 | 0 18 | | 1 | 2,520 | 7 53 | | 16 |
| 280 | 0 30 | | 1·5 | 2,580 | 8 10 | | 16·5 |
| 380 | 0 44 | | 2 | 2,630 | 8 26 | | 17 |
| 480 | 0 58 | | 2·5 | 2,690 | 8 43 | | 17·5 |
| 570 | 1 12 | | 3 | 2,740 | 9 0 | | 18 |
| 650 | 1 25 | | 3·5 | 2,800 | 9 18 | | 18·5 |
| 740 | 1 39 | | 4 | 2,850 | 9 36 | | 19 |
| 830 | 1 53 | | 4·5 | 2,900 | 9 54 | | 19·5 |
| 920 | 2 7 | | 5 | 2,950 | 10 12 | | 20 |
| 1,010 | 2 21 | | 5·5 | 3,000 | 10 30 | | 20·5 |
| 1,090 | 2 35 | | 6 | 3,050 | 10 48 | | 21 |
| 1,170 | 2 49 | | 6·5 | 3,100 | 11 7 | | 21·5 |
| 1,250 | 3 3 | | 7 | 3,150 | 11 27 | | 22 |
| 1,330 | 3 18 | | 7·5 | 3,200 | 11 47 | | 22·5 |
| 1,410 | 3 33 | | 8 | 3,240 | 12 7 | | 23 |
| 1,490 | 3 48 | | 8·5 | 3,280 | 12 28 | | 23·5 |
| 1,570 | 4 3 | | 9 | 3,330 | 12 49 | | 24 |
| 1,650 | 4 19 | | 9·5 | 3,370 | 13 10 | | 24·5 |
| 1,730 | 4 35 | | 10 | 3,410 | 13 32 | | 25 |
| 1,800 | 4 51 | | 10·5 | 3,450 | 13 55 | | 25·5 |
| 1,870 | 5 7 | | 11 | 3,490 | 14 18 | | 26 |
| 1,940 | 5 23 | | 11·5 | 3,530 | 14 42 | | 26·5 |
| 2,010 | 5 39 | | 12 | 3,560 | 15 6 | | 27 |
| 2,080 | 5 56 | | 12·5 | 3,600 | 15 31 | | 27·5 |
| 2,150 | 6 13 | | 13 | 3,630 | 15 57 | | 28 |
| 2,210 | 6 30 | | 13·5 | 3,660 | 16 24 | | 28·5 |
| 2,280 | 6 47 | | 14 | 3,700 | 16 52 | | 29 |
| 2,340 | 7 3 | | 14·5 | 3,730 | 17 22 | | 29·5 |
| 2,400 | 7 20 | | 15 | 3,760 | 17 53 | | 30 |
| 2,460 | 7 37 | | 15·5 | | | | |

**Range Table for 7-Pr. R.M.L. Gun of 200 lbs. (*Steel.*)**

**Charge, 12 oz. F.G. Powder.**

**Projectile, Common Shell.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 160 | 0 30 | | 1 | 2,060 | 8 3 | | 16 |
| 240 | 0 44 | | 1·5 | 2,110 | 8 20 | | 16·5 |
| 320 | 0 58 | | 2 | 2,160 | 8 37 | | 17 |
| 400 | 1 12 | | 2·5 | 2,210 | 8 54 | | 17·5 |
| 470 | 1 26 | | 3 | 2,260 | 9 12 | | 18 |
| 550 | 1 40 | | 3·5 | 2,300 | 9 30 | | 18·5 |
| 620 | 1 54 | | 4 | 2,350 | 9 48 | | 19 |
| 700 | 2 9 | | 4·5 | 2,390 | 10 6 | | 19·5 |
| 770 | 2 22 | | 5 | 2,440 | 10 24 | | 20 |
| 840 | 2 36 | | 5·5 | 2,480 | 10 42 | | 20·5 |
| 910 | 2 51 | | 6 | 2,530 | 11 2 | | 21 |
| 970 | 3 6 | | 6·5 | 2,570 | 11 20 | | 21·5 |
| 1,040 | 3 21 | | 7 | 2,610 | 11 38 | | 22 |
| 1,100 | 3 36 | | 7·5 | 2,650 | 11 56 | | 22·5 |
| 1,170 | 3 51 | | 8 | 2,690 | 12 14 | | 23 |
| 1,230 | 4 6 | | 8·5 | 2,730 | 12 31 | | 23·5 |
| 1,290 | 4 21 | | 9 | 2,770 | 12 48 | | 24 |
| 1,350 | 4 36 | | 9·5 | 2,810 | 13 5 | | 24·5 |
| 1,410 | 4 51 | | 10 | 2,850 | 13 22 | | 25 |
| 1,470 | 5 6 | | 10·5 | 2,890 | 13 39 | | 25·5 |
| 1,530 | 5 21 | | 11 | 2,920 | 13 56 | | 26 |
| 1,580 | 5 37 | | 11·5 | 2,960 | 14 13 | | 26·5 |
| 1,640 | 5 53 | | 12 | 2,990 | 14 30 | | 27 |
| 1,690 | 6 9 | | 12·5 | 3,030 | 14 47 | | 27·5 |
| 1,750 | 6 25 | | 13 | 3,070 | 15 4 | | 28 |
| 1,800 | 6 41 | | 13·5 | 3,100 | 15 21 | | 28·5 |
| 1,860 | 6 57 | | 14 | 3,130 | 15 38 | | 29 |
| 1,910 | 7 13 | | 14·5 | 3,170 | 15 55 | | 29·5 |
| 1,960 | 7 29 | | 15 | 3,200 | 16 12 | | 30 |
| 2,010 | 7 46 | | 15·5 | | | | |

**Range Table for 7-Pr. R.M.L. Bronze Gun, 200 lbs.**

**Charge, 8 oz. F.G. Powder.**

**Projectile, Common Shell.**

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | Secs. | Inches. | Yards. | ° ′ | Secs. | Inches. |
| 100 | 0 13 | 0·36 | 0·05 | 3,100 | 20 39 | 16·80 | 3·00 |
| 200 | 0 29 | 0·76 | 0·15 | 3,200 | | | |
| 300 | 0 47 | 1·17 | 0·20 | 3,300 | | | |
| 400 | 1 6 | 1·58 | 0·30 | 3,400 | | | |
| 500 | 1 26 | 2·00 | 0·35 | 3,500 | | | |
| 600 | 1 48 | 2·42 | 0·45 | 3,600 | | | |
| 700 | 2 11 | 2·85 | 0·50 | 3,700 | | | |
| 800 | 2 36 | 3·30 | 0·60 | 3,800 | | | |
| 900 | 3 3 | 3·76 | 0·65 | 3,900 | | | |
| 1,000 | 3 31 | 4·23 | 0·75 | 4,000 | | | |
| 1,100 | 4 0 | 4·70 | 0·85 | | | | |
| 1,200 | 4 31 | 5·18 | 0·95 | | | | |
| 1,300 | 5 5 | 5·67 | 1·00 | | | | |
| 1,400 | 5 41 | 6·17 | 1·10 | | | | |
| 1,500 | 6 19 | 6·68 | 1·20 | | | | |
| 1,600 | 6 59 | 7·20 | 1·30 | | | | |
| 1,700 | 7 41 | 7·74 | 1·40 | | | | |
| 1,800 | 8 25 | 8·30 | 1·50 | | | | |
| 1,900 | 9 11 | 8·86 | 1·60 | | | | |
| 2,000 | 9 59 | 9·43 | 1·70 | | | | |
| 2,100 | 10 49 | 10·02 | 1·80 | | | | |
| 2,200 | 11 40 | 10·63 | 1·90 | | | | |
| 2,300 | 12 33 | 11·26 | 2·00 | | | | |
| 2,400 | 13 27 | 11·90 | 2·15 | | | | |
| 2,500 | 14 23 | 12·54 | 2·25 | | | | |
| 2,600 | 15 21 | 13·20 | 2·35 | | | | |
| 2,700 | 16 21 | 13·88 | 2·50 | | | | |
| 2,800 | 17 23 | 14·58 | 2·60 | | | | |
| 2,900 | 18 27 | 15·30 | 2·75 | | | | |
| 3,000 | 19 32 | 16·04 | 2·85 | | | | |

**Range Table for 7-Pr. R.M.L. Gun of 200 lbs.** (*Steel.*)

Charge 4 oz. F.G. Powder.

Projectile, Double Shell.

| Range. | Elevation. | Time of Flight. | Fuze Scale. | Range. | Elevation. | Time of Flight. | Fuze Scale. |
|---|---|---|---|---|---|---|---|
| Yards. | ° ′ | | | Yards. | ° ′ | | |
| 700 | 8 12 | | 8·5 | 1,420 | 21 23 | | 20 |
| 730 | 8 44 | | 9 | 1,450 | 21 58 | | 20·5 |
| 760 | 9 16 | | 9·5 | 1,470 | 22 33 | | 21 |
| 800 | 9 48 | | 10 | 1,500 | 23 10 | | 21·5 |
| 830 | 10 20 | | 10·5 | 1,520 | 23 49 | | 22 |
| 860 | 10 52 | | 11 | 1,550 | 24 28 | | 22·5 |
| 900 | 11 24 | | 11·5 | 1,570 | 25 7 | | 23 |
| 930 | 11 56 | | 12 | 1,600 | 25 48 | | 23·5 |
| 960 | 12 28 | | 12·5 | 1,620 | 26 33 | | 24 |
| 1,000 | 13 0 | | 13 | 1,650 | 27 18 | | 24·5 |
| 1,030 | 13 36 | | 13·5 | 1,670 | 28 3 | | 25 |
| 1,060 | 14 12 | | 14 | 1,700 | 28 50 | | 25·5 |
| 1,100 | 14 48 | | 14·5 | 1,720 | 29 33 | | 26 |
| 1,130 | 15 24 | | 15 | 1,740 | 30 16 | | 26·5 |
| 1,160 | 16 0 | | 15·5 | 1,760 | 30 59 | | 27 |
| 1,200 | 16 36 | | 16 | 1,780 | 31 42 | | 27·5 |
| 1,230 | 17 16 | | 16·5 | 1,800 | 32 46 | | 28 |
| 1,260 | 17 56 | | 17 | 1,820 | 33 6 | | 28·5 |
| 1,300 | 18 38 | | 17·5 | 1,840 | 33 46 | | 29 |
| 1,320 | 19 10 | | 18 | 1,860 | 34 26 | | 29·5 |
| 1,350 | 19 42 | | 18·5 | 1,880 | 35 6 | | 30 |
| 1,370 | 20 14 | | 19 | | | | |
| 1,100 | 20 48 | | 19·5 | | | | |

## RANGE TABLE for 1-in. NORDENFELT GUN.

SOLID STEEL BULLET, weight 7¼ oz.; charge, 625 grains, Special Powder.

| Range. | Elevation. | Range. | Elevation. |
|---|---|---|---|
| Yards. | ° ′ | Yards. | ° ′ |
| 100 | 0 9 | 1,000 | 2 25 |
| 200 | 0 21 | 1,100 | 2 44 |
| 300 | 0 34 | 1,200 | 3 4 |
| 400 | 0 48 | 1,300 | 3 26 |
| 500 | 1 3 | 1,400 | 3 50 |
| 600 | 1 18 | 1,500 | 4 17 |
| 700 | 1 34 | 1,600 | 4 47 |
| 800 | 1 50 | 1,700 | 5 20 |
| 900 | 2 7 | 1,800 | 5 57 |

## RANGE TABLE for ·65-inch GATLING GUN.

Weight of Bullet, 1,422 grains (about 3¼ oz.); charge, 270 grains R. F. G.[2]

| Range. | Elevation. | Range. | Elevation. | Range. | Elevation. |
|---|---|---|---|---|---|
| Yards. | ° ′ | Yards. | ° ′ | Yards. | ° ′ |
| 100 | 0 8 | 800 | 1 24 | 1,500 | 3 37 |
| 200 | 0 16 | 900 | 1 39 | 1,600 | 4 1 |
| 300 | 0 25 | 1,000 | 1 55 | 1,700 | 4 27 |
| 400 | 0 35 | 1,100 | 2 13 | 1,800 | 4 54 |
| 500 | 0 46 | 1,200 | 2 32 | 1,900 | 5 23 |
| 600 | 0 58 | 1,300 | 2 52 | 2,000 | 5 54 |
| 700 | 1 10 | 1,400 | 3 14 | | |

## RANGE TABLE for ·45-inch GATLING GUN.

Weight of Bullet, 480 grains; charge, 85 grains, R. F. G.[2]

| Range. | Elevation. | Range. | Elevation. | Range. | Elevation. |
|---|---|---|---|---|---|
| Yards. | ° ′ | Yards. | ° ′ | Yards. | ° ′ |
| 100 | 0 9 | 800 | 1 54 | 1,500 | 4 25 |
| 200 | 0 20 | 900 | 2 14 | 1,600 | 4 49 |
| 300 | 0 33 | 1,000 | 2 34 | 1,700 | 5 14 |
| 400 | 0 48 | 1,100 | 2 54 | 1,800 | 5 40 |
| 500 | 1 4 | 1,200 | 3 16 | 1,900 | 6 6 |
| 600 | 1 20 | 1,300 | 3 38 | 2,000 | 6 32 |
| 700 | 1 36 | 1,400 | 4 1 | | |

# APPENDIX.

## Miscellaneous Orders.

### Care in Preserving Gearing for Working Turrets in a State of Efficiency.

The surface between the leather flaps and the glacis plates round the turrets should be frequently lubricated to prevent the rapid wearing away of the leather.

The rollers under the turrets should be periodically examined and lubricated, and the turrets be made frequently to revolve.

(*See* Circular No. 50 S, 24th June 1874.)

At sea, turret guns are to be secured in a fore and aft direction.

### (Adoption of 10 lb. Charges for 64-pr., 64 cwt., Mark III. Gun.)

A 10 lbs. charge having been adopted for use with the 60-pr., 64 cwt., Mark III. gun, my Lords Commissioners of the Admiralty are pleased to issue the following directions on the subject :—

2. 10 lb. charges will at present only be supplied to ships whose whole 64-pr. armament consists of Mark III. guns.

3. On foreign stations 10 lb. charges are only to be supplied to ships which have been fitted out in England with such charges.

4. In ships supplied with the 10 lb. charge should it be necessary at any time to exchange one of the 64-pr. guns, care is to be taken to see that a Mark III. 64-pr. is obtained in lieu ; but should no gun of this pattern be obtainable, then the 8 lb. charge only is to be used with the gun supplied, the other 64-pr. guns continuing to use both the 10 lb. and 8 lb. charges.

(*See* Circular No. 21 S, 23rd Oct. 1876.)

### Sponges for 64-pr. Guns.

It is necessary that the sponges supplied for 64-pr. guns should be carefully examined when received, to ascertain whether they are suitable for the guns on board.

The Mark II. sponge is intended to be used with Marks I. and II. 64 cwt. guns, and the Mark III. sponge with the Mark III. 64 cwt. and the 71 cwt. converted guns.

The sponges may be known by the distinguishing marks on the base of the head; they are marked II. or III., and for the gun to which they belong.

(Admiralty Letter, 8th Sept. 1879.)

### (Allowance for Collecting Gatling Gun and Martini Henry Rifle Cartridge Cases.)

The allowance for collecting and delivering into store the empty ball-cartridge cases of the Martini-Henry rifle and of the Gatling guns of ·45 calibre, will be the same as that for the Snider cases (*see* Circular No. 30 S, 23rd March 1870), except that in the case of the Martini-Henry cartridge the weight for every 1,000 will be 26 lbs. and in that of the Gatling 30 lbs.

(*See* Circular No. 27 S, 25th May 1875.)

### (Allowances for Collecting Empty Nordenfelt, ·65-inch Gatling, and Pistol Cartridge Cases.)

The following Allowances will be granted for collecting, preserving, and delivering into store empty Nordenfelt, ·65-inch Gatling, and Pistol Cartridge Cases, viz. :—

Nordenfelt Cartridges, 5*s.* per 1,000, of 158 lbs. weight.
·65-inch Gatling Cartridges, 3*s.* per 1,000, of 95 lbs. weight.
Pistol Cartridges, 2*s.* 6*d.* per 1,000, of 8 lbs. 3 ozs. weight.

2. The vouchers accompanying the delivery into store of these and the other cartridge cases, specified in article 1357 of Admiralty Instructions, will show the weight only, and on the weight payment will be made.

3. Fractional parts of 1,000 of any description of cartridge case for which payment is allowed, will be paid for in proportion.

4. The issue of these allowances will be made under the same conditions and regulations as those already laid down for the collection of other cartridges in Article 1,357, Page 429, of "Queen's Regulations and Admiralty Instructions."

(*See* Circular No. 38 S, 8th October 1880.)

### Hale's War Rockets.

The following are the latest instructions on this head:—

1. The age after which all rockets are to be returned into store has been fixed by the War Office at five years.
2. All practice with these rockets is suspended until a more trustworthy rocket is supplied.

(Admiralty letter of 13th August 1880.)

3. It is intended, however, that ships shall still carry them in case they should be required for active service.

### Effect of Machine Gun Fire on Torpedo Boats.

The following is a summary of some of the experiments carried out at Spithead on 13th May 1880.

A 1-inch Nordenfelt and 37 m.m. Hotchkiss gun were mounted on the top-gallant forecastle of the gunboat "Medway," one being on either bow.

The targets were wooden models of 2nd class torpedo boats, 60 feet long and 7½ feet extreme breadth.

*Experiment against Boat broadside on.*

The targets were moored end on to each other and 100 yards apart.

The gunboat steamed at about 7 knots, so as to pass between the targets on a direct course.

Both guns opened fire together, each at its own target, at 1,500 yards, and ceased fire when the target was abeam.

Two runs were made, the guns' crews changing guns after the first.

| | m. | sec. |
|---|---|---|
| Time of first run - - - - - | 4 | 25 |
| Do. second run - - - - - | 3 | 52 |
| Total time - - | 8 | 17 |

| | Nordenfelt. | Hotchkiss. |
|---|---|---|
| No. of rounds, first run - - - | 192 | 70 |
| Do. second run - - | 138 | 59 |
| Total - - - | 330 | 129 |
| No. of hits - - - - - - | 65 | 35 |
| Do. per minute - - | 7·8 | 4·2 |
| No. of rounds for one hit - - | 5 | 3·7 |

*Experiments against Boats end on.*

*a.* The gunboat, steaming about 7 knots, approached the target end on. Two runs were made, one for each gun, which opened fire by itself at its own target at 1,500 yards, and ceased fire when the target was abeam.

The same crew worked both guns.

| | Nordenfelt. | | Hotchkiss. | |
|---|---|---|---|---|
| | m. | sec. | m. | sec. |
| Time - - - - - | 7 | 13 | 8 | 10 |
| No. of rounds - - - | 349 | | 103 | |
| No. of hits - - - | 117 | | 54 | |
| „ per minute - | 16·2 | | 6·5 | |
| No. of rounds for one hit - | 3 | | 2 | |

*b.* As above, but fire opened at 550 yards and ceased at about 70 yards. Speed over the ground about 8 knots.

| | Nordenfelt | | Hotchkiss. | |
|---|---|---|---|---|
| | m. | sec. | m. | sec. |
| Time - - - - - - | 1 | 45 | 2 | 25 |
| No. of rounds - - - | 135 | | 50 | |
| No. of hits - - - - | 115 | | 36 | |
| Do. per minute - - | 66 | | 15 | |
| No. of rounds for one hit - | 1·2 | | 1·4 | |

# Range Table for 12-inch R.M.L. Gun of 35 tons. Based on Practice of 13. 2. 80. and 3. 3. 80.

*Minutes.*

**Length of bore, 13 feet 6 inches.**
**Calibre of gun, 12 inches.** **Weight of gun, 35 tons.**
**Charge, 140 lb. P². powder.** **Muzzle velocity = 1390 f.s.**
**No. of grooves, 9.** **Twist of rifling I. 0 to 1 turn in 35 calibres.**
**Projectile, 714 lb. Palliser shell with gas check.**

| Range. | Elevation. | Angle of descent. | Remaining velocity. | 5 minutes elevation increases or decreases the range by | 5 minutes will alter point of impact vertically or laterally at each range. | 50 per cent. of rounds should fall within | | | Time of flight. | Dangerous zone for a height of 20 feet. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Length. | Breadth. | Height. | | |
| yards. | degs. mins. | degs. mins. | f. s. | yards. | yards. | yards. | yards. | yards. | seconds | yards. |
| — | — | — | — | — | — | — | — | — | — | — |
| 100 | — | — | 1378 | — | — | — | — | — | — | — |
| 200 | — | — | 1366 | — | — | — | — | — | — | — |
| 300 | 0 9 | 0 38 | 1354 | 50·0 | 0·43 | 4·1 | 0·14 | — | 0·66 | — |
| 400 | 0 19 | 0 48 | 1342 | 50·0 | 0·58 | 5·3 | 0·18 | — | 0·87 | — |
| 500 | 0 29 | 0 58 | 1330 | 50·0 | 0·72 | 6·4 | 0·22 | 0·11 | 1·08 | — |
| 600 | 0 39 | 1 8 | 1319 | 50·0 | 0·87 | 7·5 | 0·27 | 0·15 | 1·29 | wholerange |
| 700 | 0 49 | 1 18 | 1308 | 50·0 | 1·01 | 8·6 | 0·32 | 0·20 | 1·50 | 290 |
| 800 | 0 59 | 1 28 | 1297 | 50·0 | 1·16 | 9·7 | 0·37 | 0·25 | 1·71 | 258 |
| 900 | 1 9 | 1 38 | 1286 | 50·0 | 1·31 | 10·7 | 0·42 | 0·30 | 1·92 | 230 |
| 1000 | 1 19 | 1 48 | 1275 | 50·0 | 1·45 | 11·7 | 0·47 | 0·36 | 2·13 | 209 |
| 1100 | 1 29 | 1 58 | 1264 | 50·0 | 1·60 | 12·6 | 0·52 | 0·43 | 2·35 | 191 |
| 1200 | 1 39 | 2 8 | 1253 | 50·0 | 1·74 | 13·5 | 0·57 | 0·50 | 2·57 | 176 |
| 1300 | 1 49 | 2 18 | 1243 | 50·0 | 1·89 | 14·4 | 0·62 | 0·58 | 2·79 | 164 |
| 1400 | 1 59 | 2 28 | 1233 | 50·0 | 2·03 | 15·3 | 0·67 | 0·66 | 3·01 | 154 |
| 1500 | 2 9 | 2 38 | 1223 | 45·4 | 2·18 | 16·2 | 0·72 | 0·74 | 3·23 | 144 |
| 1600 | 2 20 | 2 48 | 1213 | 45·4 | 2·32 | 17·0 | 0·77 | 0·83 | 3·45 | 135 |
| 1700 | 2 31 | 2 59 | 1203 | 45·4 | 2·47 | 17·8 | 0·82 | 0·93 | 3·67 | 126 |
| 1800 | 2 42 | 3 10 | 1194 | 45·4 | 2·61 | 18·6 | 0·87 | 1·03 | 3·89 | 119 |
| 1900 | 2 53 | 3 21 | 1185 | 45·4 | 2·76 | 19·4 | 0·92 | 1·13 | 4·11 | 112 |
| 2000 | 3 4 | 3 32 | 1176 | 45·4 | 2·91 | 20·1 | 0·97 | 1·24 | 4·33 | 106 |
| 2100 | 3 15 | 3 43 | 1167 | 45·4 | 3·05 | 20·8 | 1·02 | 1·35 | 4·55 | 101 |
| 2200 | 3 26 | 3 54 | 1158 | 45·4 | 3·20 | 21·5 | 1·07 | 1·47 | 4·77 | 96 |
| 2300 | 3 37 | 4 5 | 1149 | 45·4 | 3·34 | 22·2 | 1·12 | 1·60 | 4·99 | 92 |
| 2400 | 3 48 | 4 16 | 1140 | 45·4 | 3·49 | 22·9 | 1·17 | 1·73 | 5·21 | 88 |
| 2500 | 3 59 | 4 27 | 1132 | 45·4 | 3·63 | 23·6 | 1·22 | 1·86 | 5·43 | 84 |
| 2600 | 4 10 | 4 39 | 1124 | 45·4 | 3·78 | 24·3 | 1·27 | 2·00 | 5·65 | 81 |
| 2700 | 4 21 | 4 51 | 1116 | 45·4 | 3·92 | 25·0 | 1·32 | 2·14 | 5·87 | 78 |
| 2800 | 4 32 | 5 3 | 1108 | 45·4 | 4·07 | 25·6 | 1·38 | 2·28 | 6·09 | 75 |
| 2900 | 4 43 | 5 16 | 1100 | 45·4 | 4·21 | 26·2 | 1·44 | 2·43 | 6·32 | 72 |
| 3000 | 4 54 | 5 29 | 1092 | 45·4 | 4·36 | 26·8 | 1·50 | 2·59 | 6·55 | 69 |
| 3100 | 5 5 | 5 42 | 1085 | 45·4 | 4·51 | 27·4 | 1·56 | 2·76 | 6·78 | 66 |
| 3200 | 5 16 | 5 56 | 1078 | 45·4 | 4·65 | 28·0 | 1·62 | 2·93 | 7·02 | 63 |
| 3300 | 5 27 | 6 10 | 1071 | 45·4 | 4·80 | 28·6 | 1·68 | 3·11 | 7·26 | 61 |
| 3400 | 5 38 | 6 24 | 1064 | 45·4 | 4·94 | 29·2 | 1·74 | 3·30 | 7·50 | 58 |
| 3500 | 5 49 | 6 39 | 1057 | 45·4 | 5·09 | 29·8 | 1·80 | 3·50 | 7·75 | 56 |
| 3600 | 6 0 | 6 54 | 1051 | 41·6 | 5·23 | 30·4 | 1·86 | 3·71 | 8·00 | 54 |
| 3700 | 6 12 | 7 9 | 1045 | 41·6 | 5·38 | 31·0 | 1·92 | 3·93 | 8·25 | 52 |
| 3800 | 6 24 | 7 25 | 1040 | 41·6 | 5·52 | 31·6 | 1·98 | 4·15 | 8·50 | 50 |
| 3900 | 6 36 | 7 42 | 1035 | 41·6 | 5·67 | 32·2 | 2·04 | 4·40 | 8·77 | 48 |
| 4000 | 6 48 | 8 0 | 1030 | 41·6 | 5·81 | 32·7 | 2·10 | 4·65 | 9·06 | 47 |
| 4100 | 7 0 | 8 20 | 1025 | 41·6 | 5·96 | 33·2 | 2·16 | 4·90 | 9·35 | 45 |
| 4200 | 7 12 | 8 42 | 1020 | 38·5 | 6·11 | 33·7 | 2·22 | 5·18 | 9·64 | 43 |
| 4300 | 7 25 | 9 4 | 1015 | 38·5 | 6·25 | 34·2 | 2·28 | 5·48 | 9·93 | 41 |
| 4400 | 7 38 | 9 27 | 1010 | 38·5 | 6·40 | 34·7 | 2·34 | 5·80 | 10·23 | 39 |
| 4500 | 7 51 | 9 52 | 1005 | 35·7 | 6·54 | 35·2 | 2·40 | 6·15 | 10·53 | 38 |
| 4600 | 8 5 | 10 18 | 1000 | 35·7 | 6·69 | 35·7 | 2·47 | 6·55 | 10·85 | 36 |
| 4700 | 8 19 | 10 45 | 995 | 35·7 | 6·84 | 36·2 | 2·54 | 6·95 | 11·17 | 35 |
| 4800 | 8 33 | 11 12 | 990 | 33·3 | 6·98 | 36·7 | 2·61 | 7·35 | 11·50 | 33 |
| 4900 | 8 48 | 11 39 | 986 | 33·3 | 7·13 | 37·2 | 2·68 | 7·75 | 11·85 | 32 |
| 5000 | 9 3 | 12 9 | 982 | 33·3 | 7·27 | 37·7 | 2·75 | 8·20 | 12·22 | 30 |
| 5100 | 9 18 | 12 39 | 978 | 31·2 | 7·42 | 38·2 | 2·83 | 8·65 | 12·60 | 29 |
| 5200 | 9 34 | 13 10 | 974 | 31·2 | 7·56 | 38·6 | 2·91 | 9·10 | 13·00 | 28 |
| 5300 | 9 50 | 13 42 | 970 | 29·4 | 7·71 | 39·0 | 2·99 | 9·60 | 13·42 | 27 |
| 5400 | 10 7 | 14 18 | 966 | 27·7 | 7·85 | 39·4 | 3·07 | 10·10 | 13·88 | 26 |
| 5500 | 10 25 | 14 57 | 962 | 27·7 | 8·00 | 39·8 | 3·18 | 10·65 | 14·37 | 24 |
| 5600 | 10 43 | 15 36 | 958 | 26·3 | 8·14 | 40·2 | 3·30 | 11·25 | 14·90 | 23 |
| 5700 | 11 2 | 16 18 | 954 | 25·0 | 8·29 | 40·6 | 3·44 | 11·90 | 15·46 | 22 |
| 5800 | 11 22 | 17 9 | 950 | 25·0 | 8·43 | 41·0 | 3·58 | 12·60 | 16·10 | 21 |
| 5900 | 11 42 | 18 6 | 946 | 23·8 | 8·58 | 41·4 | 3·74 | 13·60 | 16·80 | 20 |
| 6000 | 12 3 | 20 9 | 942 | 23·8 | 8·73 | 41·8 | 3·94 | 15·40 | 17·55 | 18 |

# APPENDIX TO FINAL REPORT ON EXPERIMENTS WITH THE BASHFORTH CHRONOGRAPH, 1880.*

THE following tables have been prepared from the results of the experiments of 1867–68 and 1878–80, in order to render the results practically useful:—

Table I. gives the values $K_v, \frac{K_v}{g}$ and $\Sigma\frac{K_v}{g}$ for intervals of 5 f. s. for velocities 100 to 2800 f. s. for ogival-headed projectiles.

Table II. gives the resistance of the air in lbs. to ogival-headed shot of diameters 1 to 20 inches, when moving with a velocity between 100 and 2800 f. s.

Tables III. and IV. give the values of $\frac{d^2}{w}t$ and of $\frac{d^2}{w}s$, for velocities 100 to 2800 f. s., which are to be used as follows:— Let $V$ denote the initial velocity, and the $v$ the velocity of an ogival-headed shot (of which the diameter is $d$ inches and weight $w$ lbs.) after it has moved in an approximately straight line, resisted by the air, but unaffected by gravity, in $t$ seconds through a space $s$ feet. Let $T_v$ denote the tabular number corresponding to the velocity $v$ in Table III.; and $S_v$ that in Table IV. Then we have—

$$\frac{d^2}{w}t = T_V - T_v \qquad (1)$$

$$\frac{d^2}{w}s = S_V - S_v \qquad (2)$$

In equation (1) we have $V$, $v$, and $t$ so connected that two of these quantities being given the third can be found; and in equation (2) $V$, $v$, and $s$ are so connected that two of these being given the remaining quantity can be found by the help of the tables.

For example, suppose that an ogival-headed shot weighing 250 lbs. is fired from a 9-inch gun with an initial velocity of 1327 f. s.: Required the velocity at the distance of 300 yards, and the time of flight. Here $V = 1327$ f. s.; $w = 250$ lbs.; $d = 8 \cdot 92$ inches; and therefore $\frac{d^2}{w} = \cdot 3183$; $s = 300$ yards $= 900$ feet.

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* See also p. 132.

By equation (2) $S_v = S_V - \frac{d^2}{w} s$

$$= S_{1327} - \cdot 3183 \times 900$$
$$= 42323 \cdot 5 - 286 \cdot 5$$
$$= 42037 \cdot 0 = S_{1274 \cdot 5}$$

Therefore $v = 1274 \cdot 5$ f. s.

Again, by equation (1) $\frac{d^2}{w} t = T_V - T_v$

or, $\cdot 3183 \times t = T_{1327} - T_{1274 \cdot 5}$

$$= 231 \cdot 7173 - 231 \cdot 4971$$
$$= 0 \cdot 2202$$

or, $t = 0'' \cdot 6918$

The arrangement of the following tables differs from all others I have previously calculated, in that $S$ and $T$ increase in numerical magnitude as $v$ increases, and consequently $dT$, $dS$, and $dv$ have always the same sign. This arrangement supposes the force to be *accelerating* instead of *retarding*, but that is of no moment, as we make use only of the differences of the pairs of tabular numbers $T_V$ and $T_v$; $S_V$ and $S_v$. The mean difference of successive tabular numbers in each line has been given opposite that line.

It unfortunately happens that the equation between *time* and *space* does not admit of the formation of a general table connecting them directly together. Hence the above double process is necessary when it is required to find *what space* would be described by a shot in a *given time*, or, in *what time* a shot would describe a *given space*.

For a description of the formation of these general tables, and for practical applications of them, see my treatise on the Motion of Projectiles, p. 69; and also Principles of Gunnery, by Major Sladen, R.A., Professor of Artillery in the R.M. Academy, Woolwich.

As already stated, the weight of a cubic foot of air has been supposed to be $534 \cdot 22$ grains, which is the weight of a cubic foot of dry air at a temperature 62° F., under a pressure of 30 inches of mercury. When the range is considerable, and the weight of the air differs sensibly from $534 \cdot 22$ grains per cubic foot, this difference ought to be taken into account.

## Table I.

### Coefficients for the Cubic Law of the Resistance of the Air to Ogival-headed Shot. $g = 32\cdot1908$.

| $v$. | $K_v$. | $\frac{K_v}{g}$ | $\Sigma\frac{K_v}{g}$ | $v$. | $K_v$. | $\frac{K_v}{g}$ | $\Sigma\frac{K_v}{g}$ |
|---|---|---|---|---|---|---|---|
| f. s. | | | | f. s. | | | |
| 100 | 578·1 | 17·959 | 74·48 | 370 | 158·0 | 4·907 | 544·70 |
| 105 | 550·6 | 17·104 | 92·01 | 375 | 156·1 | 4·850 | 549·58 |
| 110 | 525·5 | 16·325 | 108·72 | 380 | 154·4 | 4·796 | 554·40 |
| 115 | 502·6 | 15·613 | 124·69 | 385 | 152·7 | 4·743 | 559·17 |
| 120 | 481·7 | 14·964 | 139·98 | 390 | 151·1 | 4·693 | 563·89 |
| 125 | 462·5 | 14·367 | 154·64 | 395 | 149·5 | 4·645 | 568·56 |
| 130 | 444·7 | 13·815 | 168·74 | 400 | 148·0 | 4·599 | 573·18 |
| 135 | 428·2 | 13·302 | 182·29 | 405 | 146·6 | 4·555 | 577·76 |
| 140 | 412·9 | 12·827 | 195·36 | 410 | 145·2 | 4·512 | 582·29 |
| 145 | 398·7 | 12·386 | 207·96 | 415 | 143·9 | 4·469 | 586·78 |
| 150 | 385·4 | 11·972 | 220·14 | 420 | 142·5 | 4·427 | 591·23 |
| 155 | 372·9 | 11·584 | 231·92 | 425 | 141·2 | 4·385 | 595·64 |
| 160 | 361·3 | 11·224 | 243·33 | 430 | 139·8 | 4·343 | 600·00 |
| 165 | 350·4 | 10·885 | 254·38 | 435 | 138·5 | 4·303 | 604·32 |
| 170 | 340·1 | 10·565 | 265·11 | 440 | 137·2 | 4·262 | 608·61 |
| 175 | 330·4 | 10·264 | 275·52 | 445 | 135·9 | 4·222 | 612·85 |
| 180 | 321·2 | 9·978 | 285·64 | 450 | 134·6 | 4·181 | 617·05 |
| 185 | 312·5 | 9·708 | 295·48 | 455 | 133·3 | 4·141 | 621·21 |
| 190 | 304·3 | 9·453 | 305·06 | 460 | 132·0 | 4·101 | 625·33 |
| 195 | 296·5 | 9·211 | 314·40 | 465 | 130·7 | 4·060 | 629·41 |
| 200 | 289·0 | 8·978 | 323·49 | 470 | 129·4 | 4·020 | 633·45 |
| 205 | 282·0 | 8·760 | 332·36 | 475 | 128·2 | 3·983 | 637·45 |
| 210 | 275·3 | 8·552 | 341·02 | 480 | 126·9 | 3·942 | 641·42 |
| 215 | 268·9 | 8·353 | 349·47 | 485 | 125·7 | 3·905 | 645·34 |
| 220 | 262·8 | 8·164 | 357·73 | 490 | 124·4 | 3·865 | 649·22 |
| 225 | 256·9 | 7·981 | 365·80 | 495 | 123·2 | 3·827 | 653·07 |
| 230 | 251·3 | 7·807 | 373·69 | 500 | 121·9 | 3·787 | 656·88 |
| 235 | 246·0 | 7·642 | 381·42 | 505 | 120·7 | 3·750 | 660·65 |
| 240 | 240·9 | 7·484 | 388·98 | 510 | 119·6 | 3·715 | 664·38 |
| 245 | 236·0 | 7·331 | 396·39 | 515 | 118·4 | 3·678 | 668·07 |
| 250 | 231·2 | 7·182 | 403·64 | 520 | 117·3 | 3·644 | 671·74 |
| 255 | 226·7 | 7·042 | 410·76 | 525 | 116·1 | 3·607 | 675·36 |
| 260 | 222·4 | 6·909 | 417·73 | 530 | 115·0 | 3·573 | 678·96 |
| 265 | 218·2 | 6·778 | 424·58 | 535 | 113·9 | 3·538 | 682·51 |
| 270 | 214·1 | 6·651 | 431·29 | 540 | 112·8 | 3·504 | 686·03 |
| 275 | 210·2 | 6·530 | 437·88 | 545 | 111·8 | 3·473 | 689·52 |
| 280 | 206·5 | 6·415 | 444·35 | 550 | 110·7 | 3·439 | 692·97 |
| 285 | 202·8 | 6·300 | 450·71 | 555 | 109·7 | 3·408 | 696·40 |
| 290 | 199·3 | 6·191 | 456·95 | 560 | 108·7 | 3·377 | 699·79 |
| 295 | 195·9 | 6·086 | 463·09 | 565 | 107·7 | 3·346 | 703·15 |
| 300 | 192·7 | 5·986 | 469·13 | 570 | 106·7 | 3·315 | 706·48 |
| 305 | 189·6 | 5·890 | 475·06 | 575 | 105·7 | 3·284 | 709·78 |
| 310 | 186·5 | 5·794 | 480·90 | 580 | 104·6 | 3·249 | 713·05 |
| 315 | 183·6 | 5·704 | 486·65 | 585 | 103·6 | 3·218 | 716·28 |
| 320 | 180·8 | 5·617 | 492·31 | 590 | 102·5 | 3·184 | 719·48 |
| 325 | 178·1 | 5·533 | 497·89 | 595 | 101·5 | 3·153 | 722·65 |
| 330 | 175·5 | 5·452 | 503·38 | 600 | 100·5 | 3·122 | 725·79 |
| 335 | 173·0 | 5·374 | 508·79 | 605 | 99·5 | 3·091 | 728·89 |
| 340 | 170·6 | 5·299 | 514·13 | 610 | 98·6 | 3·063 | 731·97 |
| 345 | 168·3 | 5·227 | 519·39 | 615 | 97·7 | 3·035 | 735·02 |
| 350 | 166·0 | 5·158 | 524·59 | 620 | 96·8 | 3·007 | 738·04 |
| 355 | 163·9 | 5·092 | 529·71 | 625 | 95·9 | 2·979 | 741·03 |
| 360 | 161·9 | 5·029 | 534·77 | 630 | 95·1 | 2·954 | 744·00 |
| 365 | 159·9 | 4·967 | 539·76 | 635 | 94·3 | 2·929 | 746·94 |

TABLE I.—*continued.*

$g=32\cdot1908.$

| $v.$ | $K_v.$ | $\frac{K_v}{g}$ | $\Sigma\frac{K_v}{g}$ | $v.$ | $K_v.$ | $\frac{K_v}{g}.$ | $\Sigma\frac{K_v}{g}$ |
|---|---|---|---|---|---|---|---|
| f. s. | | | | f. s. | | | |
| 640 | 93·5 | 2·905 | 749·86 | 925 | 75·0 | 2·330 | 891·09 |
| 645 | 92·7 | 2·880 | 752·75 | 930 | 75·0 | 2·330 | 893·42 |
| 650 | 91·9 | 2·855 | 755·62 | 935 | 75·0 | 2·330 | 895·75 |
| 655 | 91·2 | 2·833 | 758·46 | 940 | 75·0 | 2·330 | 898·08 |
| 660 | 90·5 | 2·811 | 761·28 | 945 | 75·0 | 2·330 | 900·41 |
| 665 | 89·8 | 2·790 | 764·08 | 950 | 75·0 | 2·330 | 902·74 |
| 670 | 89·1 | 2·768 | 766·86 | 955 | 75·0 | 2·330 | 905·07 |
| 675 | 88·4 | 2·746 | 769·62 | 960 | 75·0 | 2·330 | 907·40 |
| 680 | 87·7 | 2·724 | 772·35 | 965 | 75·0 | 2·330 | 909·73 |
| 685 | 87·0 | 2·703 | 775·07 | 970 | 75·0 | 2·330 | 912·06 |
| 690 | 86·3 | 2·681 | 777·75 | 975 | 75·0 | 2·330 | 914·39 |
| 695 | 85·6 | 2·659 | 780·43 | 980 | 75·0 | 2·330 | 916·72 |
| 700 | 84·9 | 2·637 | 783·08 | 985 | 75·0 | 2·330 | 919·05 |
| 705 | 84·3 | 2·619 | 785·71 | 990 | 75·0 | 2·330 | 921·38 |
| 710 | 83·7 | 2·600 | 788·31 | 995 | 75·0 | 2·330 | 923·71 |
| 715 | 83·1 | 2·581 | 790·90 | 1000 | 75·0 | 2·330 | 926·04 |
| 720 | 82·6 | 2·566 | 793·48 | 1005 | 75·0 | 2·330 | 928·37 |
| 725 | 82·1 | 2·550 | 796·04 | 1010 | 75·1 | 2·333 | 930·70 |
| 730 | 81·6 | 2·535 | 798·58 | 1015 | 75·2 | 2·336 | 933·03 |
| 735 | 81·1 | 2·519 | 801·11 | 1020 | 75·3 | 2·339 | 935·37 |
| 740 | 80·6 | 2·504 | 803·62 | 1025 | 75·7 | 2·352 | 937·71 |
| 745 | 80·1 | 2·488 | 806·11 | 1030 | 76·7 | 2·383 | 940·06 |
| 750 | 79·6 | 2·473 | 808·59 | 1035 | 78·4 | 2·435 | 942·49 |
| 755 | 79·1 | 2·457 | 811·06 | 1040 | 80·8 | 2·510 | 944·97 |
| 760 | 78·7 | 2·445 | 813·51 | 1045 | 83·8 | 2·603 | 947·53 |
| 765 | 78·3 | 2·432 | 815·95 | 1050 | 87·3 | 2·712 | 950·18 |
| 770 | 78·0 | 2·423 | 818·38 | 1055 | 90·8 | 2·821 | 952·95 |
| 775 | 77·7 | 2·414 | 820·79 | 1060 | 94·0 | 2·920 | 955·82 |
| 780 | 77·4 | 2·404 | 823·20 | 1065 | 96·6 | 3·001 | 958·78 |
| 785 | 77·1 | 2·395 | 825·60 | 1070 | 98·7 | 3·066 | 961·81 |
| 790 | 76·8 | 2·386 | 827·99 | 1075 | 100·6 | 3·125 | 964·91 |
| 795 | 76·5 | 2·376 | 830·37 | 1080 | 102·2 | 3·175 | 968·06 |
| 800 | 76·2 | 2·367 | 832·75 | 1085 | 103·7 | 3·221 | 971·26 |
| 805 | 75·9 | 2·358 | 835·11 | 1090 | 104·9 | 3·259 | 974·50 |
| 810 | 75·6 | 2·348 | 837·46 | 1095 | 105·9 | 3·290 | 977·77 |
| 815 | 75·4 | 2·342 | 839·81 | 1100 | 106·9 | 3·321 | 981·08 |
| 820 | 75·2 | 2·336 | 842·15 | 1105 | 107·8 | 3·349 | 984·41 |
| 825 | 75·1 | 2·333 | 844·48 | 1110 | 108·4 | 3·367 | 987·77 |
| 830 | 75·1 | 2·333 | 846·81 | 1115 | 108·8 | 3·380 | 991·14 |
| 835 | 75·0 | 2·330 | 849·15 | 1120 | 109·2 | 3·392 | 994·53 |
| 840 | 75·0 | 2·330 | 851·48 | 1125 | 109·5 | 3·402 | 997·93 |
| 845 | 75·0 | 2·330 | 853·81 | 1130 | 109·6 | 3·405 | 1001·33 |
| 850 | 75·0 | 2·330 | 856·14 | 1135 | 109·6 | 3·405 | 1004·74 |
| 855 | 75·0 | 2·330 | 858·47 | 1140 | 109·6 | 3·405 | 1008·14 |
| 860 | 75·0 | 2·330 | 860·80 | 1145 | 109·6 | 3·405 | 1011·55 |
| 865 | 75·0 | 2·330 | 863·13 | 1150 | 109·6 | 3·405 | 1014·96 |
| 870 | 75·0 | 2·330 | 865·46 | 1155 | 109·6 | 3·405 | 1018·36 |
| 875 | 75·0 | 2·330 | 867·79 | 1160 | 109·6 | 3·405 | 1021·76 |
| 880 | 75·0 | 2·330 | 870·12 | 1165 | 109·6 | 3·405 | 1025·17 |
| 885 | 75·0 | 2·330 | 872·45 | 1170 | 109·6 | 3·405 | 1028·57 |
| 890 | 75·0 | 2·330 | 874·78 | 1175 | 109·6 | 3·405 | 1031·98 |
| 895 | 75·0 | 2·330 | 877·11 | 1180 | 109·6 | 3·405 | 1035·38 |
| 900 | 75·0 | 2·330 | 879·44 | 1185 | 109·6 | 3·405 | 1038·79 |
| 905 | 75·0 | 2·330 | 881·77 | 1190 | 109·6 | 3·405 | 1042·19 |
| 910 | 75·0 | 2·330 | 884·10 | 1195 | 109·6 | 3·405 | 1045·60 |
| 915 | 75·0 | 2·330 | 886·43 | 1200 | 109·6 | 3·405 | 1049·00 |
| 920 | 75·0 | 2·330 | 888·76 | 1205 | 109·6 | 3·405 | 1052·41 |

## TABLE I.—*continued.*

$g = 32 \cdot 1908.$

| $v.$ | $K_{v.}$ | $\frac{K_{v.}}{g}$ | $\Sigma\frac{K_{v.}}{g}$ | $v.$ | $K_{v.}$ | $\frac{K_{v.}}{g}$ | $\Sigma\frac{K_{v.}}{g}$ |
|---|---|---|---|---|---|---|---|
| f. s. | | | | f. s. | | | |
| 1210 | 109·6 | 3·405 | 1055·81 | 1495 | 98·3 | 3·054 | 1243·36 |
| 1215 | 109·6 | 3·405 | 1059·22 | 1500 | 97·9 | 3·041 | 1246·40 |
| 1220 | 109·6 | 3·405 | 1062·62 | 1505 | 97·5 | 3·029 | 1249·44 |
| 1225 | 109·6 | 3·405 | 1066·03 | 1510 | 97·1 | 3·016 | 1252·46 |
| 1230 | 109·5 | 3·402 | 1069·43 | 1515 | 96·6 | 3·001 | 1255·47 |
| 1235 | 109·5 | 3·402 | 1072·83 | 1520 | 96·2 | 2·988 | 1258·46 |
| 1240 | 109·5 | 3·402 | 1076·23 | 1525 | 95·7 | 2·973 | 1261·45 |
| 1245 | 109·5 | 3·402 | 1079·64 | 1530 | 95·3 | 2·960 | 1264·41 |
| 1250 | 109·4 | 3·398 | 1083·04 | 1535 | 94·8 | 2·945 | 1267·36 |
| 1255 | 109·4 | 3·398 | 1086·43 | 1540 | 94·4 | 2·933 | 1270·30 |
| 1260 | 109·3 | 3·395 | 1089·83 | 1545 | 94·0 | 2·920 | 1273·23 |
| 1265 | 109·3 | 3·395 | 1093·22 | 1550 | 93·6 | 2·908 | 1276·14 |
| 1270 | 109·2 | 3·392 | 1096·62 | 1555 | 93·2 | 2·895 | 1279·04 |
| 1275 | 109·1 | 3·389 | 1100·01 | 1560 | 92·8 | 2·883 | 1281·93 |
| 1280 | 109·0 | 3·386 | 1103·40 | 1565 | 92·4 | 2·870 | 1284·81 |
| 1285 | 108·9 | 3·383 | 1106·78 | 1570 | 92·0 | 2·858 | 1287·67 |
| 1290 | 108·8 | 3·380 | 1110·16 | 1575 | 91·6 | 2·846 | 1290·53 |
| 1295 | 108·7 | 3·377 | 1113·54 | 1580 | 91·2 | 2·833 | 1293·36 |
| 1300 | 108·6 | 3·374 | 1116·92 | 1585 | 90·8 | 2·821 | 1296·19 |
| 1305 | 108·5 | 3·371 | 1120·29 | 1590 | 90·4 | 2·808 | 1299·01 |
| 1310 | 108·4 | 3·367 | 1123·66 | 1595 | 90·0 | 2·796 | 1301·81 |
| 1315 | 108·2 | 3·361 | 1127·02 | 1600 | 89·7 | 2·787 | 1304·60 |
| 1320 | 108·1 | 3·358 | 1130·38 | 1605 | 89·3 | 2·774 | 1307·38 |
| 1325 | 107·9 | 3·352 | 1133·74 | 1610 | 89·0 | 2·765 | 1310·15 |
| 1330 | 107·8 | 3·349 | 1137·09 | 1615 | 88·6 | 2·752 | 1312·91 |
| 1335 | 107·6 | 3·343 | 1140·43 | 1620 | 88·3 | 2·743 | 1315·66 |
| 1340 | 107·5 | 3·339 | 1143·77 | 1625 | 87·9 | 2·731 | 1318·39 |
| 1345 | 107·3 | 3·333 | 1147·11 | 1630 | 87·6 | 2·721 | 1321·12 |
| 1350 | 107·1 | 3·327 | 1150·44 | 1635 | 87·2 | 2·709 | 1323·83 |
| 1355 | 106·9 | 3·321 | 1153·76 | 1640 | 86·9 | 2·700 | 1326·54 |
| 1360 | 106·7 | 3·315 | 1157·08 | 1645 | 86·5 | 2·687 | 1329·23 |
| 1365 | 106·5 | 3·308 | 1160·39 | 1650 | 86·2 | 2·678 | 1331·91 |
| 1370 | 106·3 | 3·302 | 1163·70 | 1655 | 85·8 | 2·665 | 1334·59 |
| 1375 | 106·0 | 3·293 | 1166·99 | 1660 | 85·5 | 2·656 | 1337·25 |
| 1380 | 105·8 | 3·287 | 1170·29 | 1665 | 85·1 | 2·644 | 1339·90 |
| 1385 | 105·5 | 3·277 | 1173·57 | 1670 | 84·8 | 2·634 | 1342·54 |
| 1390 | 105·3 | 3·271 | 1176·84 | 1675 | 84·5 | 2·625 | 1345·16 |
| 1395 | 105·0 | 3·262 | 1180·11 | 1680 | 84·2 | 2·616 | 1347·79 |
| 1400 | 104·7 | 3·252 | 1183·36 | 1685 | 83·9 | 2·606 | 1350·40 |
| 1405 | 104·4 | 3·243 | 1186·61 | 1690 | 83·6 | 2·597 | 1353·00 |
| 1410 | 104·1 | 3·234 | 1189·85 | 1695 | 83·3 | 2·588 | 1355·59 |
| 1415 | 103·8 | 3·225 | 1193·08 | 1700 | 83·0 | 2·578 | 1358·17 |
| 1420 | 103·5 | 3·215 | 1196·30 | 1705 | 82·7 | 2·569 | 1360·75 |
| 1425 | 103·2 | 3·206 | 1199·51 | 1710 | 82·4 | 2·560 | 1363·31 |
| 1430 | 102·9 | 3·197 | 1202·71 | 1715 | 82·1 | 2·550 | 1365·87 |
| 1435 | 102·6 | 3·187 | 1205·90 | 1720 | 81·8 | 2·541 | 1368·41 |
| 1440 | 102·3 | 3·178 | 1209·09 | 1725 | 81·5 | 2·532 | 1370·95 |
| 1445 | 101·9 | 3·166 | 1212·26 | 1730 | 81·2 | 2·522 | 1373·48 |
| 1450 | 101·6 | 3·156 | 1215·42 | 1735 | 80·9 | 2·513 | 1375·99 |
| 1455 | 101·2 | 3·144 | 1218·57 | 1740 | 80·6 | 2·504 | 1378·50 |
| 1460 | 100·9 | 3·134 | 1221·71 | 1745 | 80·3 | 2·495 | 1381·00 |
| 1465 | 100·5 | 3·122 | 1224·84 | 1750 | 80·0 | 2·485 | 1383·49 |
| 1470 | 100·1 | 3·110 | 1227·95 | 1755 | 79·8 | 2·479 | 1385·97 |
| 1475 | 99·7 | 3·097 | 1231·06 | 1760 | 79·5 | 2·470 | 1388·45 |
| 1480 | 99·4 | 3·088 | 1234·15 | 1765 | 79·2 | 2·460 | 1390·91 |
| 1485 | 99·0 | 3·075 | 1237·23 | 1770 | 78·9 | 2·451 | 1393·37 |
| 1490 | 98·6 | 3·063 | 1240·30 | 1775 | 78·7 | 2·445 | 1395·82 |

## TABLE I.—*continued.*

$g = 32\cdot1908.$

| $v.$ | $K_v.$ | $\frac{K_v.}{g}$ | $\Sigma\frac{K_v.}{g}$ | $v.$ | $K_v.$ | $\frac{K_v.}{g}$ | $\Sigma\frac{K_v.}{g}$ |
|---|---|---|---|---|---|---|---|
| f. s. | | | | f. s. | | | |
| 1780 | 78·4 | 2·435 | 1398·26 | 2065 | 68·0 | 2·112 | 1525·53 |
| 1785 | 78·1 | 2·426 | 1400·69 | 2070 | 67·9 | 2·109 | 1527·64 |
| 1790 | 77·8 | 2·417 | 1403·11 | 2075 | 67·9 | 2·109 | 1529·75 |
| 1795 | 77·6 | 2·411 | 1405·52 | 2080 | 67·9 | 2·109 | 1531·85 |
| 1800 | 77·3 | 2·401 | 1407·93 | 2085 | 67·8 | 2·106 | 1533·96 |
| 1805 | 77·1 | 2·395 | 1410·33 | 2090 | 67·8 | 2·106 | 1536·07 |
| 1810 | 76·8 | 2·386 | 1412·72 | 2095 | 67·8 | 2·106 | 1538·17 |
| 1815 | 76·5 | 2·376 | 1415·10 | 2100 | 67·8 | 2·106 | 1540·28 |
| 1820 | 76·2 | 2·367 | 1417·47 | 2105 | 67·7 | 2·103 | 1542·38 |
| 1825 | 76·0 | 2·361 | 1419·84 | 2110 | 67·7 | 2·103 | 1544·49 |
| 1830 | 75·7 | 2·352 | 1422·19 | 2115 | 67·7 | 2·103 | 1546·59 |
| 1835 | 75·5 | 2·345 | 1424·54 | 2120 | 67·6 | 2·100 | 1548·69 |
| 1840 | 75·2 | 2·336 | 1426·88 | 2125 | 67·6 | 2·100 | 1550·79 |
| 1845 | 75·0 | 2·330 | 1429·21 | 2130 | 67·6 | 2·100 | 1552·89 |
| 1850 | 74·7 | 2·321 | 1431·53 | 2135 | 67·5 | 2·097 | 1554·99 |
| 1855 | 74·5 | 2·314 | 1433·85 | 2140 | 67·5 | 2·097 | 1557·09 |
| 1860 | 74·2 | 2·305 | 1436·16 | 2145 | 67·4 | 2·094 | 1559·18 |
| 1865 | 73·9 | 2·296 | 1438·46 | 2150 | 67·4 | 2·094 | 1561·28 |
| 1870 | 73·6 | 2·286 | 1440·75 | 2155 | 67·3 | 2·091 | 1563·37 |
| 1875 | 73·4 | 2·280 | 1443·04 | 2160 | 67·3 | 2·091 | 1565·46 |
| 1880 | 73·1 | 2·271 | 1445·31 | 2165 | 67·2 | 2·088 | 1567·55 |
| 1885 | 72·9 | 2·265 | 1447·58 | 2170 | 67·2 | 2·088 | 1569·64 |
| 1890 | 72·6 | 2·255 | 1449·84 | 2175 | 67·2 | 2·088 | 1571·73 |
| 1895 | 72·4 | 2·249 | 1452·09 | 2180 | 67·2 | 2·088 | 1573·81 |
| 1900 | 72·1 | 2·240 | 1454·34 | 2185 | 67·1 | 2·084 | 1575·90 |
| 1905 | 71·9 | 2·234 | 1456·57 | 2190 | 67·1 | 2·084 | 1577·98 |
| 1910 | 71·6 | 2·224 | 1458·80 | 2195 | 67·0 | 2·081 | 1580·07 |
| 1915 | 71·4 | 2·218 | 1461·02 | 2200 | 67·0 | 2·081 | 1582·15 |
| 1920 | 71·2 | 2·212 | 1463·24 | 2205 | 66·9 | 2·078 | 1584·23 |
| 1925 | 71·0 | 2·206 | 1465·45 | 2210 | 66·9 | 2·078 | 1586·30 |
| 1930 | 70· | 2·199 | 1467·65 | 2215 | 66·8 | 2·075 | 1588·38 |
| 1935 | 70· | 2·193 | 1469·85 | 2220 | 66·8 | 2·075 | 1590·46 |
| 1940 | 70·4 | 2·187 | 1472·04 | 2225 | 66·8 | 2·075 | 1592·53 |
| 1945 | 70·2 | 2·181 | 1474·22 | 2230 | 66·8 | 2·075 | 1594·61 |
| 1950 | 70·0 | 2·175 | 1476·40 | 2235 | 66·7 | 2·072 | 1596·68 |
| 1955 | 69·8 | 2·168 | 1478·57 | 2240 | 66·7 | 2·072 | 1598·75 |
| 1960 | 69·7 | 2·165 | 1480·74 | 2245 | 66·6 | 2·069 | 1600·82 |
| 1965 | 69·5 | 2·159 | 1482·90 | 2250 | 66·6 | 2·069 | 1602·89 |
| 1970 | 69·4 | 2·156 | 1485·05 | 2255 | 66·6 | 2·069 | 1604·96 |
| 1975 | 69·3 | 2·153 | 1487·21 | 2260 | 66·5 | 2·066 | 1607·03 |
| 1980 | 69·2 | 2·150 | 1489·36 | 2265 | 66·5 | 2·066 | 1609·09 |
| 1985 | 69·1 | 2·147 | 1491·51 | 2270 | 66·4 | 2·063 | 1611·16 |
| 1990 | 69·0 | 2·143 | 1493·65 | 2275 | 66·3 | 2·060 | 1613·22 |
| 1995 | 68·9 | 2·140 | 1495·79 | 2280 | 66·2 | 2·056 | 1615·28 |
| 2000 | 68·8 | 2·137 | 1497·93 | 2285 | 66·1 | 2·053 | 1617·33 |
| 2005 | 68·7 | 2·134 | 1500·07 | 2290 | 65·9 | 2·047 | 1619·38 |
| 2010 | 68·6 | 2·131 | 1502·20 | 2295 | 65·7 | 2·041 | 1621·43 |
| 2015 | 68·5 | 2·128 | 1504·33 | 2300 | 65·5 | 2·035 | 1623·46 |
| 2020 | 68·4 | 2·125 | 1506·46 | 2305 | 65·3 | 2·029 | 1625·50 |
| 2025 | 68·4 | 2·125 | 1508·58 | 2310 | 65·0 | 2·019 | 1627·52 |
| 2030 | 68·3 | 2·122 | 1510·71 | 2315 | 64·7 | 2·010 | 1629·53 |
| 2035 | 68·3 | 2·122 | 1512·83 | 2320 | 64·4 | 2·001 | 1631·54 |
| 2040 | 68·2 | 2·119 | 1514·95 | 2325 | 64·1 | 1·991 | 1633·54 |
| 2045 | 68·2 | 2·119 | 1517·07 | 2330 | 63·8 | 1·982 | 1635·52 |
| 2050 | 68·1 | 2·116 | 1519·18 | 2335 | 63·5 | 1·973 | 1637·50 |
| 2055 | 68·1 | 2·116 | 1521·30 | 2340 | 63·2 | 1·963 | 1639·47 |
| 2060 | 68·0 | 2·112 | 1523·41 | 2345 | 62·9 | 1·954 | 1641·43 |

TABLE I.—*continued.*

$g = 32\cdot1908.$

| $v.$ | $K_v.$ | $\frac{K_v}{g}$ | $\Sigma\frac{K_v}{g}$ | $v.$ | $K_v.$ | $\frac{K_v}{g}$ | $\Sigma\frac{K_v}{g}$ |
|---|---|---|---|---|---|---|---|
| f. s. | | | | f. s. | | | |
| 2350 | 62·6 | 1·945 | 1643·38 | 2590 | 52·5 | 1·631 | 1727·37 |
| 2355 | 62·3 | 1·935 | 1645·32 | 2595 | 52·5 | 1·631 | 1729·00 |
| 2360 | 62·0 | 1·926 | 1647·25 | 2600 | 52·4 | 1·628 | 1730·63 |
| 2365 | 61·7 | 1·917 | 1649·17 | 2605 | 52·4 | 1·628 | 1732·26 |
| 2370 | 61·4 | 1·907 | 1651·08 | 2610 | 52·4 | 1·628 | 1733·88 |
| 2375 | 61·1 | 1·898 | 1652·98 | 2615 | 52·4 | 1·628 | 1735·51 |
| 2380 | 60·8 | 1·889 | 1654·88 | 2620 | 52·4 | 1·628 | 1737·14 |
| 2385 | 60·5 | 1·879 | 1656·76 | 2625 | 52·4 | 1·628 | 1738·77 |
| 2390 | 60·2 | 1·870 | 1658·63 | 2630 | 52·3 | 1·625 | 1740·39 |
| 2395 | 59·9 | 1·861 | 1660·50 | 2635 | 52·3 | 1·625 | 1742·02 |
| 2400 | 59·6 | 1·851 | 1662·36 | 2640 | 52·3 | 1·625 | 1743·64 |
| 2405 | 59·3 | 1·842 | 1664·20 | 2645 | 52·3 | 1·625 | 1745·27 |
| 2410 | 59·0 | 1·833 | 1666·04 | 2650 | 52·3 | 1·625 | 1746·89 |
| 2415 | 58·7 | 1·824 | 1667·87 | 2655 | 52·2 | 1·622 | 1748·52 |
| 2420 | 58·4 | 1·814 | 1669·69 | 2660 | 52·2 | 1·622 | 1750·14 |
| 2425 | 58·1 | 1·805 | 1671·50 | 2665 | 52·2 | 1·622 | 1751·76 |
| 2430 | 57·8 | 1·796 | 1673·30 | 2670 | 52·2 | 1·622 | 1753·38 |
| 2435 | 57·5 | 1·786 | 1675·09 | 2675 | 52·2 | 1·622 | 1755·01 |
| 2440 | 57·2 | 1·777 | 1676·87 | 2680 | 52·2 | 1·622 | 1756·63 |
| 2445 | 57·0 | 1·771 | 1678·64 | 2685 | 52·1 | 1·618 | 1758·25 |
| 2450 | 56·7 | 1·761 | 1680·41 | 2690 | 52·1 | 1·618 | 1759·87 |
| 2455 | 56·5 | 1·755 | 1682·17 | 2695 | 52·1 | 1·618 | 1761·48 |
| 2460 | 56·2 | 1·746 | 1683·92 | 2700 | 52·1 | 1·618 | 1763·10 |
| 2465 | 56·0 | 1·740 | 1685·66 | 2705 | 52·1 | 1·618 | 1764·72 |
| 2470 | 55·7 | 1·730 | 1687·40 | 2710 | 52·1 | 1·618 | 1766·34 |
| 2475 | 55·5 | 1·724 | 1689·12 | 2715 | 52·0 | 1·615 | 1767·95 |
| 2480 | 55·2 | 1·715 | 1690·84 | 2720 | 52·0 | 1·615 | 1769·57 |
| 2485 | 55·0 | 1·709 | 1692·55 | 2725 | 52·0 | 1·615 | 1771·18 |
| 2490 | 54·8 | 1·702 | 1694·26 | 2730 | 52·0 | 1·615 | 1772·80 |
| 2495 | 54·6 | 1·696 | 1695·96 | 2735 | 52·0 | 1·615 | 1774·41 |
| 2500 | 54·4 | 1·690 | 1697·65 | 2740 | 52·0 | 1·615 | 1776·03 |
| 2505 | 54·2 | 1·684 | 1699·34 | 2745 | 52·0 | 1·615 | 1777·64 |
| 2510 | 54·0 | 1·678 | 1701·02 | 2750 | 52·0 | 1·615 | 1779·26 |
| 2515 | 53·8 | 1·671 | 1702·69 | 2755 | 52·0 | 1·615 | 1780·87 |
| 2520 | 53·7 | 1·668 | 1704·36 | 2760 | 52·0 | 1·615 | 1782·49 |
| 2525 | 53·5 | 1·662 | 1706·03 | 2765 | 52·0 | 1·615 | 1784·10 |
| 2530 | 53·4 | 1·659 | 1707·69 | 2770 | 52·0 | 1·615 | 1785·72 |
| 2535 | 53·2 | 1·653 | 1709·35 | 2775 | 52·0 | 1·615 | 1787·33 |
| 2540 | 53·1 | 1·650 | 1711·00 | 2780 | 52·0 | 1·615 | 1788·95 |
| 2545 | 53·0 | 1·646 | 1712·64 | 2785 | 52·0 | 1·615 | 1790·56 |
| 2550 | 52·9 | 1·643 | 1714·29 | 2790 | 52·0 | 1·615 | 1792·18 |
| 2555 | 52·8 | 1·640 | 1715·93 | 2795 | 52·0 | 1·615 | 1793·79 |
| 2560 | 52·7 | 1·637 | 1717·57 | 2800 | 52·0 | 1·615 | 1795·41 |
| 2565 | 52·7 | 1·637 | 1719·21 | | | | |
| 2570 | 52·6 | 1·634 | 1720·84 | | | | |
| 2575 | 52·6 | 1·634 | 1722·48 | | | | |
| 2580 | 52·5 | 1·631 | 1724·11 | | | | |
| 2585 | 52·5 | 1·631 | 1725·74 | | | | |

## Table II.

Table showing the Resistance of the Air in pounds to Ogival-headed Shot, from one to twenty inches in Diameter, for specified Velocities.

| v. | 1 in. | 2 in. | 3 in. | 4 in. | 5 in. | 6 in. | 7 in. | 8 in. | 9 in. | 10 in. | 11 in. | 12 in. | 13 in. | 14 in. | 15 in. | 16 in. | 17 in. | 18 in. | 19 in. | 20 in. | v. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f. s. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | f. s. |
| 100 | 0·018 | 0·1 | 0·2 | 0·3 | 0·5 | 0·6 | 0·9 | 1·2 | 1·5 | 1·8 | 2·2 | 2·6 | 3·0 | 3·5 | 4·1 | 4·6 | 5·2 | 5·8 | 6·5 | 7·2 | 100 |
| 150 | 0·040 | 0·2 | 0·4 | 0·6 | 1·0 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 13 | 14 | 16 | 150 |
| 200 | 0·072 | 0·3 | 0·6 | 1·1 | 1·8 | 3 | 4 | 5 | 6 | 7 | 9 | 10 | 12 | 14 | 16 | 18 | 21 | 23 | 26 | 29 | 200 |
| 250 | 0·112 | 0·4 | 1 | 2 | 3 | 4 | 5 | 7 | 9 | 11 | 14 | 16 | 19 | 22 | 25 | 29 | 32 | 36 | 41 | 45 | 250 |
| 300 | 0·162 | 0·6 | 1 | 3 | 4 | 6 | 8 | 10 | 13 | 16 | 20 | 23 | 27 | 32 | 36 | 41 | 47 | 52 | 58 | 65 | 300 |
| 350 | 0·221 | 0·9 | 2 | 4 | 6 | 8 | 11 | 14 | 18 | 22 | 27 | 32 | 37 | 43 | 50 | 57 | 64 | 72 | 80 | 88 | 350 |
| 400 | 0·294 | 1·2 | 3 | 5 | 7 | 11 | 14 | 19 | 24 | 29 | 36 | 42 | 50 | 58 | 66 | 75 | 85 | 95 | 106 | 118 | 400 |
| 450 | 0·381 | 1·5 | 3 | 6 | 10 | 14 | 19 | 24 | 31 | 38 | 46 | 55 | 64 | 75 | 86 | 98 | 110 | 123 | 138 | 152 | 450 |
| 500 | 0·473 | 1·9 | 4 | 8 | 12 | 17 | 23 | 30 | 38 | 47 | 57 | 68 | 80 | 93 | 106 | 121 | 137 | 153 | 171 | 189 | 500 |
| 550 | 0·572 | 2·3 | 5 | 9 | 14 | 20 | 28 | 36 | 46 | 57 | 69 | 82 | 97 | 112 | 129 | 146 | 165 | 185 | 206 | 229 | 550 |
| 600 | 0·674 | 2·7 | 6 | 11 | 17 | 24 | 33 | 43 | 55 | 67 | 82 | 97 | 114 | 132 | 152 | 173 | 195 | 218 | 243 | 270 | 600 |
| 650 | 0·784 | 3·1 | 7 | 13 | 20 | 28 | 38 | 50 | 64 | 78 | 95 | 113 | 132 | 154 | 176 | 200 | 227 | 254 | 283 | 314 | 650 |
| 700 | 0·905 | 3·6 | 8 | 14 | 23 | 33 | 44 | 58 | 73 | 91 | 110 | 130 | 153 | 177 | 204 | 232 | 262 | 293 | 327 | 362 | 700 |
| 750 | 1·043 | 4·2 | 9 | 17 | 26 | 38 | 51 | 67 | 84 | 104 | 126 | 150 | 176 | 204 | 235 | 267 | 301 | 338 | 377 | 417 | 750 |
| 800 | 1·212 | 4·8 | 11 | 19 | 30 | 44 | 59 | 78 | 98 | 121 | 147 | 175 | 205 | 238 | 273 | 310 | 350 | 393 | 438 | 485 | 800 |
| 850 | 1·430 | 5·7 | 13 | 23 | 36 | 51 | 70 | 92 | 116 | 143 | 173 | 206 | 242 | 280 | 322 | 366 | 413 | 463 | 516 | 572 | 850 |
| 900 | 1·698 | 6·8 | 15 | 27 | 42 | 61 | 83 | 109 | 138 | 170 | 205 | 245 | 287 | 333 | 382 | 435 | 491 | 550 | 613 | 679 | 900 |
| 950 | 1·997 | 8·0 | 18 | 32 | 50 | 72 | 98 | 128 | 162 | 200 | 242 | 288 | 337 | 391 | 449 | 511 | 577 | 647 | 721 | 799 | 950 |
| 1000 | 2·329 | 9·3 | 21 | 37 | 58 | 84 | 114 | 149 | 189 | 233 | 282 | 335 | 394 | 456 | 524 | 596 | 673 | 755 | 841 | 932 | 1000 |
| 1050 | 3·140 | 12·5 | 28 | 50 | 79 | 113 | 154 | 201 | 254 | 314 | 380 | 452 | 531 | 615 | 707 | 804 | 907 | 1,017 | 1,134 | 1,256 | 1050 |
| 1100 | 4·420 | 17·7 | 40 | 71 | 111 | 159 | 217 | 283 | 358 | 442 | 535 | 636 | 747 | 866 | 995 | 1,132 | 1,277 | 1,432 | 1,596 | 1,768 | 1100 |
| 1150 | 5·179 | 20·7 | 47 | 83 | 129 | 186 | 254 | 331 | 419 | 518 | 627 | 746 | 875 | 1,015 | 1,165 | 1,326 | 1,497 | 1,678 | 1,870 | 2,072 | 1150 |
| 1200 | 5·884 | 23·5 | 53 | 94 | 147 | 212 | 288 | 377 | 477 | 588 | 712 | 847 | 994 | 1,153 | 1,324 | 1,506 | 1,700 | 1,906 | 2,124 | 2,354 | 1200 |
| 1250 | 6·637 | 26·5 | 60 | 106 | 166 | 239 | 325 | 425 | 538 | 664 | 808 | 956 | 1,122 | 1,301 | 1,493 | 1,699 | 1,918 | 2,150 | 2,396 | 2,655 | 1250 |
| 1300 | 7·413 | 29·7 | 67 | 119 | 185 | 267 | 363 | 474 | 600 | 741 | 807 | 1,067 | 1,253 | 1,453 | 1,668 | 1,898 | 2,142 | 2,402 | 2,676 | 2,965 | 1300 |

TABLE II.—*continued.*

| v. | 1 in. | 2 in. | 3 in. | 4 in. | 5 in. | 6 in. | 7 in. | 8 in. | 9 in. | 10 in. | 11 in. | 12 in. | 13 in. | 14 in. | 15 in. | 16 in. | 17 in. | 18 in. | 19 in. | 20 in. | v. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f. s. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | f. s. |
| 1350 | 8·186 | 32·7 | 74 | 131 | 205 | 295 | 401 | 524 | 663 | 819 | 991 | 1,179 | 1,383 | 1,604 | 1,842 | 2,096 | 2,366 | 2,652 | 2,955 | 3,274 | 1350 |
| 1400 | 8·924 | 35·7 | 80 | 142 | 223 | 321 | 437 | 571 | 723 | 892 | 1,080 | 1,285 | 1,508 | 1,749 | 2,008 | 2,285 | 2,579 | 2,891 | 3,222 | 3,570 | 1400 |
| 1450 | 9·621 | 38·5 | 87 | 154 | 241 | 346 | 471 | 616 | 779 | 962 | 1,164 | 1,385 | 1,626 | 1,886 | 2,165 | 2,463 | 2,780 | 3,117 | 3,473 | 3,848 | 1450 |
| 1500 | 10·263 | 41·1 | 92 | 164 | 257 | 369 | 503 | 657 | 831 | 1,026 | 1,242 | 1,478 | 1,734 | 2,012 | 2,309 | 2,627 | 2,966 | 3,325 | 3,705 | 4,105 | 1500 |
| 1550 | 10·829 | 43·3 | 97 | 173 | 271 | 390 | 531 | 693 | 877 | 1,083 | 1,310 | 1,559 | 1,830 | 2,122 | 2,487 | 2,772 | 3,130 | 3,509 | 3,909 | 4,332 | 1550 |
| 1600 | 11·416 | 45·7 | 103 | 183 | 285 | 411 | 559 | 731 | 925 | 1,142 | 1,381 | 1,644 | 1,929 | 2,238 | 2,569 | 2,922 | 3,299 | 3,699 | 4,121 | 4,566 | 1600 |
| 1650 | 12·030 | 48·1 | 108 | 192 | 301 | 433 | 589 | 770 | 974 | 1,203 | 1,456 | 1,732 | 2,033 | 2,358 | 2,707 | 3,080 | 3,477 | 3,898 | 4,343 | 4,812 | 1650 |
| 1700 | 12·666 | 50·7 | 114 | 203 | 317 | 456 | 621 | 811 | 1,026 | 1,267 | 1,533 | 1,824 | 2,141 | 2,483 | 2,850 | 3,242 | 3,660 | 4,101 | 4,572 | 5,066 | 1700 |
| 1750 | 13·318 | 53·3 | 120 | 213 | 333 | 479 | 653 | 852 | 1,079 | 1,332 | 1,611 | 1,918 | 2,251 | 2,610 | 2,997 | 3,409 | 3,849 | 4,315 | 4,808 | 5,327 | 1750 |
| 1800 | 14·003 | 56·0 | 126 | 224 | 350 | 504 | 686 | 896 | 1,134 | 1,400 | 1,694 | 2,016 | 2,367 | 2,745 | 3,151 | 3,585 | 4,047 | 4,537 | 5,055 | 5,601 | 1800 |
| 1850 | 14·697 | 58·8 | 132 | 235 | 367 | 529 | 720 | 940 | 1,190 | 1,469 | 1,777 | 2,115 | 2,482 | 2,879 | 3,305 | 3,760 | 4,245 | 4,759 | 5,303 | 5,876 | 1850 |
| 1900 | 15·364 | 61·5 | 138 | 246 | 384 | 553 | 753 | 983 | 1,244 | 1,536 | 1,859 | 2,212 | 2,597 | 3,011 | 3,457 | 3,933 | 4,440 | 4,978 | 5,546 | 6,146 | 1900 |
| 1950 | 16·127 | 64·5 | 145 | 258 | 403 | 581 | 790 | 1,032 | 1,306 | 1,613 | 1,951 | 2,322 | 2,725 | 3,161 | 3,629 | 4,129 | 4,661 | 5,225 | 5,822 | 6,451 | 1950 |
| 2000 | 17·096 | 68·4 | 154 | 274 | 427 | 615 | 838 | 1,093 | 1,385 | 1,710 | 2,069 | 2,462 | 2,889 | 3,351 | 3,847 | 4,377 | 4,941 | 5,539 | 6,172 | 6,838 | 2000 |
| 2050 | 18·230 | 72·9 | 164 | 292 | 456 | 656 | 893 | 1,167 | 1,477 | 1,823 | 2,206 | 2,625 | 3,081 | 3,573 | 4,102 | 4,667 | 5,268 | 5,907 | 6,581 | 7,292 | 2050 |
| 2100 | 19·504 | 78·0 | 176 | 312 | 488 | 702 | 956 | 1,248 | 1,580 | 1,950 | 2,360 | 2,809 | 3,296 | 3,823 | 4,388 | 4,993 | 5,637 | 6,319 | 7,041 | 7,802 | 2100 |
| 2150 | 20·811 | 83·2 | 187 | 333 | 520 | 749 | 1,020 | 1,332 | 1,686 | 2,081 | 2,518 | 2,997 | 3,517 | 4,079 | 4,682 | 5,328 | 6,014 | 6,743 | 7,513 | 8,324 | 2150 |
| 2200 | 22·159 | 88·6 | 199 | 355 | 554 | 798 | 1,086 | 1,418 | 1,795 | 2,216 | 2,681 | 3,191 | 3,745 | 4,343 | 4,986 | 5,673 | 6,404 | 7,180 | 7,999 | 8,864 | 2200 |
| 2250 | 23·567 | 94·3 | 212 | 377 | 589 | 848 | 1,155 | 1,508 | 1,909 | 2,357 | 2,852 | 3,393 | 3,983 | 4,619 | 5,303 | 6,033 | 6,811 | 7,636 | 8,508 | 9,427 | 2250 |
| 2300 | 24·760 | 99·0 | 223 | 396 | 619 | 891 | 1,213 | 1,585 | 2,006 | 2,476 | 2,996 | 3,565 | 4,184 | 4,853 | 5,571 | 6,339 | 7,156 | 8,022 | 8,938 | 9,904 | 2300 |
| 2350 | 25·242 | 101·0 | 227 | 404 | 631 | 909 | 1,237 | 1,615 | 2,045 | 2,524 | 3,054 | 3,635 | 4,266 | 4,947 | 5,679 | 6,462 | 7,295 | 8,178 | 9,112 | 10,097 | 2350 |
| 2400 | 25·588 | 102·4 | 230 | 409 | 640 | 921 | 1,254 | 1,638 | 2,073 | 2,559 | 3,096 | 3,685 | 4,324 | 5,015 | 5,757 | 6,551 | 7,395 | 8,291 | 9,237 | 10,235 | 2400 |
| 2450 | 25·897 | 103·6 | 233 | 414 | 647 | 932 | 1,269 | 1,657 | 2,098 | 2,590 | 3,134 | 3,729 | 4,377 | 5,076 | 5,827 | 6,630 | 7,484 | 8,391 | 9,349 | 10,359 | 2450 |
| 2500 | 26·406 | 105·6 | 238 | 422 | 660 | 951 | 1,294 | 1,690 | 2,139 | 2,641 | 3,195 | 3,802 | 4,463 | 5,176 | 5,941 | 6,760 | 7,631 | 8,556 | 9,533 | 10,562 | 2500 |
| 2550 | 27·243 | 109·0 | 245 | 436 | 681 | 981 | 1,335 | 1,744 | 2,207 | 2,724 | 3,296 | 3,923 | 4,604 | 5,340 | 6,130 | 6,974 | 7,873 | 8,827 | 9,835 | 10,897 | 2550 |
| 2600 | 28·614 | 114·5 | 258 | 458 | 715 | 1,030 | 1,402 | 1,831 | 2,318 | 2,861 | 3,462 | 4,120 | 4,836 | 5,608 | 6,438 | 7,325 | 8,269 | 9,271 | 10,330 | 11,446 | 2600 |
| 2650 | 30·241 | 121·0 | 272 | 484 | 756 | 1,089 | 1,482 | 1,935 | 2,450 | 3,024 | 3,659 | 4,355 | 5,111 | 5,927 | 6,804 | 7,742 | 8,740 | 9,798 | 10,917 | 12,096 | 2650 |
| 2700 | 31·847 | 127·4 | 287 | 510 | 796 | 1,146 | 1,561 | 2,038 | 2,580 | 3,185 | 3,853 | 4,586 | 5,382 | 6,242 | 7,166 | 8,153 | 9,204 | 10,318 | 11,497 | 12,739 | 2700 |
| 2750 | 33·587 | 134·3 | 302 | 537 | 840 | 1,209 | 1,646 | 2,150 | 2,721 | 3,359 | 4,064 | 4,837 | 5,676 | 6,583 | 7,557 | 8,598 | 9,707 | 10,882 | 12,125 | 13,435 | 2750 |
| 2800 | 35·452 | 141·8 | 319 | 567 | 886 | 1,276 | 1,737 | 2,269 | 2,872 | 3,545 | 4,290 | 5,105 | 5,991 | 6,949 | 7,977 | 9,076 | 10,246 | 11,486 | 12,798 | 14,181 | 2800 |

## Table III.

### A General Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 10 | 75·399 | 77·111 | 78·790 | 80·437 | 82·052 | 83·636 | 85·190 | 86·715 | 88·212 | 89·682 | 1·584 |
| 11 | 91·125 | 92·542 | 93·934 | 95·301 | 96·644 | 97·964 | 99·261 | *00·536 | *01·789 | *03·021 | 1·320 |
| 12 | 1 04·232 | 05·423 | 06·595 | 07·748 | 08·883 | 09·999 | 11·097 | 12·178 | 13·243 | 14·291 | 1·116 |
| 13 | 1 15·323 | 16·339 | 17·340 | 18·326 | 19·297 | 20·254 | 21·196 | 22·124 | 23·039 | 23·941 | ·957 |
| 14 | 24·830 | 25·706 | 26·570 | 27·422 | 28·262 | 29·091 | 29·908 | 30·714 | 31·509 | 32·294 | ·829 |
| 15 | 33·068 | 33·832 | 34·586 | 35·331 | 36·066 | 36·792 | 37·508 | 38·215 | 38·913 | 39·602 | ·726 |
| 16 | 1 40·283 | 40·955 | 41·618 | 42·273 | 42·920 | 43·559 | 44·190 | 44·813 | 45·429 | 46·038 | ·639 |
| 17 | 46·640 | 47·235 | 47·823 | 48·404 | 48·978 | 49·546 | 50·107 | 50·662 | 51·211 | 51·754 | ·568 |
| 18 | 52·291 | 52·822 | 53·347 | 53·867 | 54·381 | 54·890 | 55·393 | 55·890 | 56·382 | 56·869 | ·509 |
| 19 | 1 57·351 | 57·828 | 58·300 | 58·767 | 59·229 | 59·686 | 60·138 | 60·586 | 61·029 | 61·468 | ·457 |
| 20 | 61·902 | 62·332 | 62·758 | 63·180 | 63·598 | 64·012 | 64·422 | 64·828 | 65·230 | 65·628 | ·414 |
| 21 | 66·022 | 66·412 | 66·798 | 67·181 | 67·560 | 67·936 | 68·308 | 68·676 | 69·041 | 69·403 | ·375 |
| 22 | 1 69·762 | 70·118 | 70·470 | 70·819 | 71·165 | 71·508 | 71·848 | 72·185 | 72·519 | 72·850 | ·343 |
| 23 | 73·179 | 73·505 | 73·828 | 74·148 | 74·465 | 74·780 | 75·092 | 75·401 | 75·708 | 76·012 | ·315 |
| 24 | 76·314 | 76·613 | 76·909 | 77·203 | 77·494 | 77·783 | 78·070 | 78·354 | 78·636 | 78·916 | ·289 |
| 25 | 1 79·194 | 79·470 | 70·743 | 80·014 | 80·283 | 80·550 | 80·815 | 81·078 | 81·339 | 81·598 | ·267 |
| 26 | 81·855 | 82·110 | 82·363 | 82·614 | 82·863 | 83·110 | 83·355 | 83·598 | 83·839 | 84·079 | ·247 |
| 27 | 84·317 | 84·553 | 84·787 | 85·020 | 85·251 | 85·481 | 85·709 | 85·935 | 86·160 | 86·382 | ·230 |
| 28 | 1 86·604 | 86·824 | 87·042 | 87·259 | 87·474 | 87·688 | 87·900 | 88·111 | 88·320 | 88·528 | ·214 |
| 29 | 88·734 | 88·939 | 89·143 | 89·345 | 89·546 | 89·745 | 89·943 | 90·140 | 90·335 | 90·529 | ·199 |
| 30 | 90·721 | 90·912 | 91·102 | 91·291 | 91·478 | 91·664 | 91·849 | 92·033 | 92·216 | 92·397 | ·186 |
| 31 | 1 92·577 | 92·756 | 92·934 | 93·111 | 93·287 | 93·461 | 93·634 | 93·806 | 93·971 | 94·147 | ·174 |
| 32 | 94·316 | 94·484 | 94·651 | 94·817 | 94·982 | 95·146 | 95·309 | 95·471 | 95·632 | 95·792 | ·164 |
| 33 | 95·951 | 96·109 | 96·266 | 96·422 | 96·577 | 96·731 | 96·884 | 97·036 | 97·187 | 97·338 | ·154 |
| 34 | 1 97·488 | 97·637 | 97·785 | 97·932 | 98·078 | 98·223 | 98·367 | 98·510 | 98·652 | 98·794 | ·145 |
| 35 | 98·935 | 99·075 | 99·214 | 99·352 | 99·490 | 99·627 | 99·763 | 99·898 | *00·032 | *00·166 | ·137 |
| 36 | 2 00·299 | 00·431 | 00·562 | 00·692 | 00·822 | 00·951 | 01·079 | 01·206 | 01·333 | 01·459 | ·129 |
| 37 | 2 01·585 | 01·710 | 01·834 | 01·957 | 02·080 | 02·202 | 02·323 | 02·443 | 02·563 | 02·682 | ·122 |
| 38 | 02·801 | 02·919 | 03·036 | 03·152 | 03·268 | 03·383 | 03·497 | 03·610 | 03·723 | 03·835 | ·115 |
| 39 | 03·947 | 04·058 | 04·168 | 04·278 | 04·387 | 04·496 | 04·604 | 04·711 | 04·818 | 04·924 | ·109 |
| 40 | 20 5·0299 | 5·1349 | 5·2393 | 5·3432 | 5·4466 | 5·5494 | 5·6517 | 5·7534 | 5·8546 | 5·9553 | ·1028 |
| 41 | 6·0554 | 6·1550 | 6·2540 | 6·3525 | 6·4505 | 6·5480 | 6·6450 | 6·7414 | 6·8373 | 6·9327 | ·0975 |
| 42 | 7·0276 | 7·1220 | 7·2159 | 7·3093 | 7·4022 | 7·4947 | 7·5867 | 7·6782 | 7·7693 | 7·8599 | ·0925 |
| 43 | 20 7·9501 | 8·0398 | 8·1291 | 8·2179 | 8·3063 | 8·3942 | 8·4817 | 8·5687 | 8·6553 | 8·7415 | ·0879 |
| 44 | 8·8272 | 8·9125 | 8·9974 | 9·0819 | 9·1660 | 9·2497 | 9·3330 | 9·4159 | 9·4984 | 9·5805 | ·0837 |
| 45 | 9·6622 | 9·7435 | 9·8244 | 9·9050 | 9·9852 | *0·0651 | *0·1446 | *0·2237 | *0·3025 | *0·3809 | ·0799 |
| 46 | 21 0·4590 | 0·5367 | 0·6140 | 0·6910 | 0·7677 | 0·8440 | 0·9200 | 0·9956 | 1·0709 | 1·1459 | ·0763 |
| 47 | 1·2205 | 1·2948 | 1·3687 | 1·4423 | 1·5156 | 1·5886 | 1·6613 | 1·7336 | 1·8056 | 1·8773 | ·0730 |
| 48 | 1·9487 | 2·0198 | 2·0906 | 2·1611 | 2·2313 | 2·3012 | 2·3708 | 2·4401 | 2·5091 | 2·5779 | ·0699 |
| 49 | 21 2·6464 | 2·7146 | 2·7825 | 2·8501 | 2·9174 | 2·9845 | 3·0513 | 3·1178 | 3·1841 | 3·2501 | ·0671 |
| 50 | 3·3159 | 3·3814 | 3·4466 | 3·5116 | 3·5763 | 3·6608 | 3·7050 | 3·7689 | 3·8326 | 3·8960 | ·0645 |
| 51 | 3·9592 | 4·0221 | 4·0848 | 4·1472 | 4·2094 | 4·2713 | 4·3330 | 4·3944 | 4·4556 | 4·5165 | ·0619 |
| 52 | 21 4·5772 | 4·6377 | 4·6979 | 4·7579 | 4·8177 | 4·8773 | 4·9367 | 4·9958 | 5·0547 | 5·1134 | ·0596 |
| 53 | 5·1719 | 5·2302 | 5·2882 | 5·3460 | 5·4036 | 5·4610 | 5·5182 | 5·5752 | 5·6320 | 5·6886 | ·0574 |
| 54 | 5·7450 | 5·8012 | 5·8572 | 5·9130 | 5·9686 | 6·0240 | 6·0792 | 6·1342 | 6·1890 | 6·2436 | ·0554 |
| 55 | 21 6·2980 | 6·3522 | 6·4062 | 6·4600 | 6·5136 | 6·5670 | 6·6202 | 6·6732 | 6·7260 | 6·7786 | ·0534 |
| 56 | 6·8311 | 6·8834 | 6·9355 | 6·9874 | 7·0391 | 7·0907 | 7·1421 | 7·1933 | 7·2444 | 7·2953 | ·0516 |
| 57 | 7·3460 | 7·3965 | 7·4469 | 7·4971 | 7·5471 | 7·5970 | 7·6467 | 7·6962 | 7·7456 | 7·7948 | ·0499 |
| 58 | 21 7·8438 | 7·8928 | 7·9417 | 7·9904 | 8·0389 | 8·0873 | 8·1356 | 8·1837 | 8·2316 | 8·2793 | ·0483 |
| 59 | 8·3271 | 8·3746 | 8·4220 | 8·4692 | 8·5163 | 8·5632 | 8·6100 | 8·6566 | 8·7031 | 8·7494 | ·0468 |
| 60 | 8·7957 | 8·8417 | 8·8877 | 8·9334 | 8·9791 | 9·0246 | 9·0700 | 9·1152 | 9·1603 | 9·2052 | ·0454 |
| 61 | 21 9·2501 | 9·2947 | 9·3393 | 9·3837 | 9·4280 | 9·4721 | 9·5161 | 9·5600 | 9·6037 | 9·6473 | ·0441 |
| 62 | 9·6908 | 9·7341 | 9·7773 | 9·8204 | 9·8633 | 9·9062 | 9·9489 | 9·9914 | *0·0338 | *0·0761 | ·0428 |
| 63 | 22 0·1183 | 0·1604 | 0·2023 | 0·2441 | 0·2858 | 0·3273 | 0·3687 | 0·4100 | 0·4512 | 0·4922 | ·0415 |
| 64 | 22 0·5332 | 0·5740 | 0·6147 | 0·6552 | 0·6957 | 0·7360 | 0·7762 | 0·8163 | 0·8563 | 0·8962 | ·0403 |
| 65 | 0·9359 | 0·9755 | 1·0151 | 1·0544 | 1·0937 | 1·1328 | 1·1718 | 1·2107 | 1·2495 | 1·2881 | ·0391 |
| 66 | 1·3267 | 1·3651 | 1·4034 | 1·4416 | 1·4797 | 1·5177 | 1·5555 | 1·5933 | 1·6309 | 1·6684 | ·0379 |
| 67 | 22 1·7059 | 1·7432 | 1·7804 | 1·8175 | 1·8545 | 1·8914 | 1·9281 | 1·9648 | 2·0014 | 2·0378 | ·0368 |
| 68 | 2·0742 | 2·1105 | 2·1466 | 2·1827 | 2·2186 | 2·2545 | 2·2902 | 2·3259 | 2·3614 | 2·3969 | ·0358 |
| 69 | 2·4322 | 2·4675 | 2·5027 | 2·5377 | 2·5727 | 2·6076 | 2·6424 | 2·6771 | 2·7117 | 2·7462 | ·0348 |

## TABLE III.—*continued.*

### A General Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 70 | 22 2·7806 | 2·8150 | 2·8492 | 2·8833 | 2·9174 | 2·9513 | 2·9852 | 3·0189 | 3·0526 | 3·0862 | ·0339 |
| 71 | 3·1196 | 3·1530 | 3·1863 | 3·2195 | 3·2526 | 3·2856 | 3·3185 | 3·3513 | 3·3840 | 3·4167 | ·0330 |
| 72 | 3·4492 | 3·4816 | 3·5140 | 3·5462 | 3·5784 | 3·6105 | 3·6424 | 3·6743 | 3·7061 | 3·7378 | ·0320 |
| 73 | 22 3·7694 | 3·8009 | 3·8323 | 3·8636 | 3·8949 | 3·9260 | 3·9571 | 3·9881 | 4·0189 | 4·0497 | ·0311 |
| 74 | 4·0804 | 4·1110 | 4·1416 | 4·1720 | 4·2024 | 4·2326 | 4·2628 | 4·2929 | 4·3230 | 4·3529 | ·0302 |
| 75 | 4·3828 | 4·4125 | 4·4422 | 4·4719 | 4·5014 | 4·5308 | 4·5602 | 4·5895 | 4·6187 | 4·6478 | ·0294 |
| 76 | 22 4·6769 | 4·7058 | 4·7347 | 4·7635 | 4·7922 | 4·8208 | 4·8493 | 4·8777 | 4·9060 | 4·9343 | ·0286 |
| 77 | 4·9624 | 4·9905 | 5·0185 | 5·0464 | 5·0742 | 5·1020 | 5·1296 | 5·1572 | 5·1847 | 5·2121 | ·0277 |
| 78 | 5·2394 | 5·2666 | 5·2937 | 5·3208 | 5·3478 | 5·3747 | 5·4015 | 5·4282 | 5·4549 | 5·4814 | ·0268 |
| 79 | 22 5·5079 | 5·5343 | 5·5606 | 5·5869 | 5·6130 | 5·6391 | 5·6652 | 5·6911 | 5·7170 | 5·7428 | ·0261 |
| 80 | 5·7685 | 5·7941 | 5·8197 | 5·8452 | 5·8706 | 5·8959 | 5·9212 | 5·9463 | 5·9714 | 5·9965 | ·0253 |
| 81 | 6·0214 | 6·0463 | 6·0711 | 6·0959 | 6·1205 | 6·1451 | 6·1696 | 6·1941 | 6·2184 | 6·2427 | ·0245 |
| 82 | 22 6·2669 | 6·2910 | 6·3151 | 6·3390 | 6·3629 | 6·3867 | 6·4104 | 6·4340 | 6·4576 | 6·4810 | ·0237 |
| 83 | 6·5044 | 6·5277 | 6·5509 | 6·5740 | 6·5971 | 6·6201 | 6·6430 | 6·6658 | 6·6885 | 6·7111 | ·0229 |
| 84 | 6·7337 | 6·7562 | 6·7786 | 6·8009 | 6·8232 | 6·8454 | 6·8675 | 6·8895 | 6·9114 | 6·9333 | ·0221 |
| 85 | 22 6·9551 | 6·9768 | 6·9984 | 7·0200 | 7·0415 | 7·0629 | 7·0842 | 7·1055 | 7·1267 | 7·1478 | ·0214 |
| 86 | 7·1688 | 7·1898 | 7·2107 | 7·2315 | 7·2522 | 7·2729 | 7·2935 | 7·3140 | 7·3345 | 7·3549 | ·0206 |
| 87 | 7·3752 | 7·3954 | 7·4156 | 7·4357 | 7·4558 | 7·4757 | 7·4956 | 7·5155 | 7·5353 | 7·5550 | ·0199 |
| 88 | 22 7·5746 | 7·5942 | 7·6137 | 7·6332 | 7·6526 | 7·6719 | 7·6912 | 7·7104 | 7·7295 | 7·7486 | ·0193 |
| 89 | 7·7677 | 7·7866 | 7·8055 | 7·8244 | 7·8431 | 7·8618 | 7·8805 | 7·8991 | 7·9176 | 7·9360 | ·0187 |
| 90 | 7·9544 | 7·9727 | 7·9909 | 8·0091 | 8·0272 | 8·0452 | 8·0632 | 8·0812 | 8·0990 | 8·1168 | ·0180 |
| 91 | 22 8·1346 | 8·1523 | 8·1699 | 8·1875 | 8·2050 | 8·2225 | 8·2399 | 8·2573 | 8·2746 | 8·2918 | ·0174 |
| 92 | 8·3090 | 8·3261 | 8·3432 | 8·3602 | 8·3772 | 8·3941 | 8·4109 | 8·4277 | 8·4445 | 8·4611 | ·0169 |
| 93 | 8·4778 | 8·4943 | 8·5109 | 8·5273 | 8·5437 | 8·5601 | 8·5764 | 8·5927 | 8·6089 | 8·6250 | ·0163 |
| 94 | 22 8·6411 | 8·6572 | 8·6732 | 8·6892 | 8·7051 | 8·7209 | 8·7367 | 8·7525 | 8·7682 | 8·7838 | ·0158 |
| 95 | 8·7994 | 8·8150 | 8·8305 | 8·8459 | 8·8613 | 8·8767 | 8·8920 | 8·9073 | 8·9225 | 8·9376 | ·0153 |
| 96 | 8·9528 | 8·9678 | 8·9828 | 8·9978 | 9·0128 | 9·0276 | 9·0425 | 9·0573 | 9·0720 | 9·0867 | ·0149 |
| 97 | 22 9·1014 | 9·1160 | 9·1306 | 9·1451 | 9·1595 | 9·1740 | 9·1884 | 9·2027 | 9·2170 | 9·2312 | ·0144 |
| 98 | 9·2454 | 9·2596 | 9·2737 | 9·2878 | 9·3018 | 9·3158 | 9·3298 | 9·3437 | 9·3575 | 9·3713 | ·0140 |
| 99 | 9·3851 | 9·3989 | 9·4126 | 9·4262 | 9·4398 | 9·4534 | 9·4670 | 9·4805 | 9·4939 | 9·5073 | ·0136 |
| 100 | 22 9·5207 | 9·5340 | 9·5473 | 9·5606 | 9·5738 | 9·5869 | 9·6001 | 9·6132 | 9·6262 | 9·6392 | ·0132 |
| 101 | 9·6522 | 9·6651 | 9·6780 | 9·6908 | 9·7036 | 9·7164 | 9·7291 | 9·7418 | 9·7544 | 9·7670 | ·0127 |
| 102 | 9·7796 | 9·7921 | 9·8046 | 9·8170 | 9·8294 | 9·8417 | 9·8540 | 9·8662 | 9·8783 | 9·8904 | ·0123 |
| 103 | 22 9·9024 | 9·9144 | 9·9262 | 9·9380 | 9·9496 | 9·9612 | 9·9727 | 9·9841 | 9·9954 | *0·0068 | ·0115 |
| 104 | 23 0·0177 | 0·0287 | 0·0396 | 0·0504 | 0·0610 | 0·0716 | 0·0820 | 0·0923 | 0·1025 | 0·1126 | ·0105 |
| 105 | 0·1226 | 0·1325 | 0·1423 | 0·1520 | 0·1615 | 0·1710 | 0·1804 | 0·1897 | 0·1988 | 0·2079 | ·0094 |
| 106 | 23 0·2170 | 0·2259 | 0·2347 | 0·2435 | 0·2522 | 0·2609 | 0·2694 | 0·2780 | 0·2864 | 0·2948 | ·0086 |
| 107 | 0·3031 | 0·3114 | 0·3196 | 0·3278 | 0·3359 | 0·3439 | 0·3520 | 0·3599 | 0·3678 | 0·3757 | ·0080 |
| 108 | 0·3835 | 0·3913 | 0·3990 | 0·4067 | 0·4143 | 0·4219 | 0·4295 | 0·4370 | 0·4445 | 0·4519 | ·0076 |
| 109 | 23 0·4593 | 0·4667 | 0·4740 | 0·4813 | 0·4885 | 0·4958 | 0·5030 | 0·5101 | 0·5172 | 0·5243 | ·0072 |
| 110 | 0·5314 | 0·5384 | 0·5454 | 0·5524 | 0·5593 | 0·5662 | 0·5731 | 0·5800 | 0·5868 | 0·5936 | ·0069 |
| 111 | 0·6004 | 0·6071 | 0·6139 | 0·6206 | 0·6272 | 0·6339 | 0·6405 | 0·6471 | 0·6537 | 0·6603 | ·0066 |
| 112 | 23 0·6668 | 0·6733 | 0·6798 | 0·6863 | 0·6928 | 0·6992 | 0·7056 | 0·7120 | 0·7184 | 0·7248 | ·0064 |
| 113 | 0·7311 | 0·7374 | 0·7437 | 0·7500 | 0·7563 | 0·7625 | 0·7688 | 0·7750 | 0·7812 | 0·7874 | ·0062 |
| 114 | 0·7936 | 0·7997 | 0·8059 | 0·8120 | 0·8181 | 0·8242 | 0·8303 | 0·8364 | 0·8424 | 0·8484 | ·0061 |
| 115 | 23 0·8545 | 0·8605 | 0·8665 | 0·8726 | 0·8787 | 0·8847 | 0·8906 | 0·8965 | 0·9024 | 0·9083 | ·0059 |
| 116 | 0·9142 | 0·9200 | 0·9259 | 0·9317 | 0·9375 | 0·9433 | 0·9490 | 0·9548 | 0·9605 | 0·9663 | ·0058 |
| 117 | 0·9720 | 0·9777 | 0·9833 | 0·9890 | 0·9947 | 1·0003 | 1·0059 | 1·0115 | 1·0171 | 1·0227 | ·0056 |
| 118 | 23 1·0283 | 1·0338 | 1·0394 | 1·0449 | 1·0504 | 1·0559 | 1·0614 | 1·0669 | 1·0723 | 1·0778 | ·0055 |
| 119 | 1·0832 | 1·0886 | 1·0940 | 1·0994 | 1·1048 | 1·1101 | 1·1154 | 1·1208 | 1·1261 | 1·1314 | ·0054 |
| 120 | 1·1367 | 1·1420 | 1·1475 | 1·1524 | 1·1578 | 1·1630 | 1·1682 | 1·1734 | 1·1786 | 1·1838 | ·0052 |
| 121 | 23 1·1889 | 1·1941 | 1·1992 | 1·2043 | 1·2095 | 1·2146 | 1·2196 | 1·2247 | 1·2298 | 1·2348 | ·0051 |
| 122 | 1·2399 | 1·2449 | 1·2499 | 1·2549 | 1·2599 | 1·2649 | 1·2698 | 1·2748 | 1·2797 | 1·2847 | ·0050 |
| 123 | 1·2896 | 1·2945 | 1·2994 | 1·3043 | 1·3091 | 1·3140 | 1·3188 | 1·3237 | 1·3285 | 1·3333 | ·0049 |
| 124 | 23 1·3381 | 1·3429 | 1·3477 | 1·3524 | 1·3572 | 1·3619 | 1·3667 | 1·3714 | 1·3761 | 1·3808 | ·0047 |
| 125 | 1·3855 | 1·3902 | 1·3948 | 1·3995 | 1·4041 | 1·4088 | 1·4134 | 1·4180 | 1·4226 | 1·4272 | ·0046 |
| 126 | 1·4318 | 1·4364 | 1·4410 | 1·4455 | 1·4501 | 1·4546 | 1·4591 | 1·4636 | 1·4681 | 1·4726 | ·0045 |
| 127 | 23 1·4771 | 1·4816 | 1·4860 | 1·4905 | 1·4949 | 1·4993 | 1·5038 | 1·5082 | 1·5126 | 1·5170 | ·0044 |
| 128 | 1·5214 | 1·5257 | 1·5301 | 1·5345 | 1·5388 | 1·5431 | 1·5475 | 1·5518 | 1·5561 | 1·5604 | ·0043 |
| 129 | 1·5647 | 1·5690 | 1·5732 | 1·5775 | 1·5818 | 1·5860 | 1·5902 | 1·5945 | 1·5987 | 1·6029 | ·0042 |

## TABLE III.—*continued.*

### A General Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

| $v$. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 130 | 23 1·6071 | 1·6113 | 1·6155 | 1·6196 | 1·6238 | 1·6280 | 1·6321 | 1·6362 | 1·6404 | 1·6445 | ·0042 |
| 131 | 1·6486 | 1·6527 | 1·6568 | 1·6609 | 1·6650 | 1·6690 | 1·6731 | 1·6772 | 1·6812 | 1·6852 | ·0041 |
| 132 | 1·6893 | 1·6933 | 1·6973 | 1·7013 | 1·7053 | 1·7093 | 1·7133 | 1·7173 | 1·7212 | 1·7252 | ·0040 |
| 133 | 23 1·7291 | 1·7331 | 1·7370 | 1·7410 | 1·7449 | 1·7488 | 1·7527 | 1·7566 | 1·7605 | 1·7644 | ·0039 |
| 134 | 1·7682 | 1·7721 | 1·7760 | 1·7798 | 1·7837 | 1·7875 | 1·7913 | 1·7952 | 1·7990 | 1·8028 | ·0038 |
| 135 | 1·8066 | 1·8104 | 1·8142 | 1·8179 | 1·8217 | 1·8255 | 1·8292 | 1·8330 | 1·8367 | 1·8405 | ·0038 |
| 136 | 23 1·8442 | 1·8479 | 1·8517 | 1·8554 | 1·8591 | 1·8628 | 1·8665 | 1·8702 | 1·8738 | 1·8775 | ·0037 |
| 137 | 1·8812 | 1·8848 | 1·8885 | 1·8921 | 1·8958 | 1·8994 | 1·9030 | 1·9067 | 1·9103 | 1·9139 | ·0036 |
| 138 | 1·9175 | 1·9211 | 1·9247 | 1·9282 | 1·9318 | 1·9354 | 1·9390 | 1·9425 | 1·9461 | 1·9496 | ·0036 |
| 139 | 23 1·9532 | 1·9567 | 1·9602 | 1·9638 | 1·9673 | 1·9708 | 1·9743 | 1·9778 | 1·9813 | 1·9848 | ·0035 |
| 140 | 1·9883 | 1·9918 | 1·9952 | 1·9987 | 2·0022 | 2·0056 | 2·0091 | 2·0125 | 2·0160 | 2·0194 | ·0035 |
| 141 | 2·0228 | 2·0263 | 2·0297 | 2·0331 | 2·0365 | 2·0399 | 2·0433 | 2·0467 | 2·0501 | 2·0535 | ·0034 |
| 142 | 23 2·0569 | 2·0602 | 2·0636 | 2·0670 | 2·0703 | 2·0737 | 2·0770 | 2·0804 | 2·0837 | 2·0870 | ·0034 |
| 143 | 2·0904 | 2·0937 | 2·0970 | 2·1003 | 2·1036 | 2·1069 | 2·1102 | 2·1135 | 2·1168 | 2·1201 | ·0033 |
| 144 | 2·1234 | 2·1267 | 2·1299 | 2·1332 | 2·1364 | 2·1397 | 2·1430 | 2·1462 | 2·1494 | 2·1527 | ·0033 |
| 145 | 23 2·1559 | 2·1591 | 2·1624 | 2·1656 | 2·1688 | 2·1720 | 2·1752 | 2·1784 | 2·1816 | 2·1848 | ·0032 |
| 146 | 2·1880 | 2·1912 | 2·1944 | 2·1975 | 2·2007 | 2·2039 | 2·2071 | 2·2102 | 2·2134 | 2·2165 | ·0032 |
| 147 | 2·2.97 | 2·2228 | 2·2260 | 2·2291 | 2·2322 | 2·2354 | 2·2385 | 2·2416 | 2·2447 | 2·2478 | ·0031 |
| 148 | 23 2·2509 | 2·2540 | 2·2571 | 2·2602 | 2·2633 | 2·2664 | 2·2695 | 2·2726 | 2·2757 | 2·2787 | ·0031 |
| 149 | 2·2818 | 2·2849 | 2·2879 | 2·2910 | 2·2940 | 2·2971 | 2·3001 | 2·3032 | 2·3062 | 2·3093 | ·0030 |
| 150 | 2·3123 | 2·3153 | 2·3183 | 2·3214 | 2·3244 | 2·3274 | 2·3304 | 2·3334 | 2·3364 | 2·3394 | ·0030 |
| 151 | 23 2·3424 | 2·3454 | 2·3484 | 2·3514 | 2·3543 | 2·3573 | 2·3603 | 2·3633 | 2·3662 | 2·3692 | ·0030 |
| 152 | 2·3722 | 2·3751 | 2·3781 | 2·3810 | 2·3840 | 2·3869 | 2·3899 | 2·3928 | 2·3958 | 2·3987 | ·0029 |
| 153 | 2·4016 | 2·4046 | 2·4075 | 2·4104 | 2·4133 | 2·4162 | 2·4192 | 2·4221 | 2·4250 | 2·4279 | ·0029 |
| 154 | 23 2·4308 | 2·4337 | 2·4366 | 2·4395 | 2·4424 | 2·4453 | 2·4481 | 2·4510 | 2·4539 | 2·4568 | ·0029 |
| 155 | 2·4597 | 2·4625 | 2·4654 | 2·4683 | 2·4711 | 2·4740 | 2·4768 | 2·4797 | 2·4825 | 2·4854 | ·0029 |
| 156 | 2·4882 | 2·4911 | 2·4939 | 2·4967 | 2·4996 | 2·5024 | 2·5052 | 2·5080 | 2·5108 | 2·5137 | ·0028 |
| 157 | 23 2·5165 | 2·5193 | 2·5221 | 2·5249 | 2·5277 | 2·5305 | 2·5333 | 2·5361 | 2·5389 | 2·5416 | ·0028 |
| 158 | 2·5444 | 2·5472 | 2·5500 | 2·5528 | 2·5555 | 2·5583 | 2·5611 | 2·5638 | 2·5666 | 2·5693 | ·0028 |
| 159 | 2·5721 | 2·5748 | 2·5776 | 2·5803 | 2·5831 | 2·5858 | 2·5885 | 2·5913 | 2·5940 | 2·5967 | ·0027 |
| 160 | 23 2·5994 | 2·6022 | 2·6049 | 2·6076 | 2·6103 | 2·6130 | 2·6157 | 2·6184 | 2·6211 | 2·6238 | ·0027 |
| 161 | 2·6265 | 2·6292 | 2·6319 | 2·6346 | 2·6373 | 2·6400 | 2·6426 | 2·6453 | 2·6480 | 2·6506 | ·0027 |
| 162 | 2·6533 | 2·6560 | 2·6586 | 2·6613 | 2·6640 | 2·6666 | 2·6693 | 2·6719 | 2·6745 | 2·6772 | ·0026 |
| 163 | 23 2·6798 | 2·6825 | 2·6851 | 2·6877 | 2·6903 | 2·6930 | 2·6956 | 2·6982 | 2·7008 | 2·7034 | ·0026 |
| 164 | 2·7061 | 2·7087 | 2·7113 | 2·7139 | 2·7165 | 2·7191 | 2·7217 | 2·7243 | 2·7268 | 2·7294 | ·0026 |
| 165 | 2·7320 | 2·7346 | 2·7372 | 2·7398 | 2·7423 | 2·7449 | 2·7475 | 2·7500 | 2·7526 | 2·7552 | ·0026 |
| 166 | 23 2·7577 | 2·7603 | 2·7628 | 2·7654 | 2·7679 | 2·7705 | 2·7730 | 2·7756 | 2·7781 | 2·7806 | ·0025 |
| 167 | 2·7832 | 2·7857 | 2·7882 | 2·7908 | 2·7933 | 2·7958 | 2·7983 | 2·8008 | 2·8034 | 2·8059 | ·0025 |
| 168 | 2·8084 | 2·8109 | 2·8134 | 2·8159 | 2·8184 | 2·8209 | 2·8234 | 2·8258 | 2·8283 | 2·8308 | ·0025 |
| 169 | 23 2·8333 | 2·8358 | 2·8383 | 2·8407 | 2·8432 | 2·8457 | 2·8481 | 2·8506 | 2·8531 | 2·8555 | ·0025 |
| 170 | 2·8580 | 2·8604 | 2·8629 | 2·8653 | 2·8678 | 2·8702 | 2·8726 | 2·8751 | 2·8775 | 2·8799 | ·0024 |
| 171 | 2·8824 | 2·8848 | 2·8872 | 2·8896 | 2·8921 | 2·8945 | 2·8969 | 2·8993 | 2·9017 | 2·9041 | ·0024 |
| 172 | 23 2·9065 | 2·9089 | 2·9113 | 2·9137 | 2·9161 | 2·9185 | 2·9209 | 2·9233 | 2·9257 | 2·9281 | ·0024 |
| 173 | 2·9304 | 2·9328 | 2·9352 | 2·9376 | 2·9399 | 2·9423 | 2·9447 | 2·9470 | 2·9494 | 2·9518 | ·0024 |
| 174 | 2·9541 | 2·9565 | 2·9588 | 2·9612 | 2·9635 | 2·9659 | 2·9682 | 2·9705 | 2·9729 | 2·9752 | ·0023 |
| 175 | 23 2·9776 | 2·9799 | 2·9822 | 2·9845 | 2·9869 | 2·9892 | 2·9915 | 2·9938 | 2·9961 | 2·9985 | ·0023 |
| 176 | 3·0008 | 3·0031 | 3·0054 | 3·0077 | 3·0100 | 3·0123 | 3·0146 | 3·0169 | 3·0192 | 3·0215 | ·0023 |
| 177 | 3·0237 | 3·0260 | 3·0283 | 3·0306 | 3·0329 | 3·0351 | 3·0374 | 3·0397 | 3·0420 | 3·0442 | ·0023 |
| 178 | 23 3·0465 | 3·0488 | 3·0510 | 3·0533 | 3·0555 | 3·0578 | 3·0600 | 3·0623 | 3·0645 | 3·0668 | ·0023 |
| 179 | 3·0690 | 3·0713 | 3·0735 | 3·0757 | 3·0780 | 3·0802 | 3·0824 | 3·0847 | 3·0869 | 3·0891 | ·0022 |
| 180 | 3·0913 | 3·0935 | 3·0958 | 3·0980 | 3·1002 | 3·1024 | 3·1045 | 3·1068 | 3·1090 | 3·1112 | ·0022 |
| 181 | 23 3·1134 | 3·1156 | 3·1178 | 3·1200 | 3·1222 | 3·1244 | 3·1266 | 3·1287 | 3·1309 | 3·1331 | ·0022 |
| 182 | 3·1353 | 3·1375 | 3·1396 | 3·1418 | 3·1440 | 3·1461 | 3·1483 | 3·1505 | 3·1526 | 3·1548 | ·0022 |
| 183 | 3·1569 | 3·1591 | 3·1613 | 3·1634 | 3·1656 | 3·1677 | 3·1698 | 3·1720 | 3·1741 | 3·1763 | ·0021 |
| 184 | 23 3·1784 | 3·1805 | 3·1827 | 3·1848 | 3·1869 | 3·1891 | 3·1912 | 3·1933 | 3·1954 | 3·1975 | ·0021 |
| 185 | 3·1997 | 3·2018 | 3·2039 | 3·2060 | 3·2081 | 3·2102 | 3·2123 | 3·2144 | 3·2165 | 3·2186 | ·0021 |
| 186 | 3·2207 | 3·2228 | 3·2249 | 3·2270 | 3·2291 | 3·2312 | 3·2333 | 3·2353 | 3·2374 | 3·2395 | ·0021 |
| 187 | 23 3·2416 | 3·2437 | 3·2457 | 3·2478 | 3·2499 | 3·2520 | 3·2540 | 3·2561 | 3·2582 | 3·2602 | ·0021 |
| 188 | 3·2623 | 3·2643 | 3·2664 | 3·2685 | 3·2705 | 3·2726 | 3·2746 | 3·2767 | 3·2787 | 3·2808 | ·0021 |
| 189 | 3·2828 | 3·2848 | 3·2869 | 3·2889 | 3·2909 | 3·2930 | 3·2950 | 3·2970 | 3·2991 | 3·3011 | ·0020 |

## Table III.—*continued.*

### A General Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 190 | 23 3·3031 | 3·3051 | 3·3072 | 3·3092 | 3·3112 | 3·3132 | 3·3152 | 3·3172 | 3·3192 | 3·3212 | ·0020 |
| 191 | 3·3233 | 3·3253 | 3·3273 | 3·3293 | 3·3313 | 3·3333 | 3·3353 | 3·3372 | 3·3392 | 3·3412 | ·0020 |
| 192 | 3·3432 | 3·3452 | 3·3472 | 3·3492 | 3·3511 | 3·3531 | 3·3551 | 3·3571 | 3·3590 | 3·3610 | ·0020 |
| 193 | 23 3·3630 | 3·3649 | 3·3669 | 3·3689 | 3·3708 | 3·3728 | 3·3747 | 3·3767 | 3·3786 | 3·3806 | ·0020 |
| 194 | 3·3825 | 3·3845 | 3·3864 | 3·3884 | 3·3903 | 3·3922 | 3·3942 | 3·3961 | 3·3980 | 3·4000 | ·0019 |
| 195 | 3·4019 | 3·4038 | 3·4057 | 3·4077 | 3·4096 | 3·4115 | 3·4134 | 3·4153 | 3·4172 | 3·4192 | ·0019 |
| 196 | 23 3·4211 | 3·4230 | 3·4249 | 3·4268 | 3·4287 | 3·4306 | 3·4325 | 3·4344 | 3·4362 | 3·4381 | ·0019 |
| 197 | 3·4400 | 3·4419 | 3·4438 | 3·4457 | 3·4476 | 3·4494 | 3·4513 | 3·4532 | 3·4550 | 3·4569 | ·0019 |
| 198 | 3·4588 | 3·4606 | 3·4625 | 3·4644 | 3·4662 | 3·4681 | 3·4699 | 3·4718 | 3·4736 | 3·4755 | ·0019 |
| 199 | 23 3·4773 | 3·4791 | 3·4810 | 3·4828 | 3·4846 | 3·4865 | 3·4883 | 3·4901 | 3·4920 | 3·4938 | ·0018 |
| 200 | 3·4956 | 3·4974 | 3·4992 | 3·5010 | 3·5028 | 3·5047 | 3·5065 | 3·5083 | 3·5101 | 3·5119 | ·0018 |
| 201 | 3·5137 | 3·5155 | 3·5172 | 3·5190 | 3·5208 | 3·5226 | 3·5244 | 3·5262 | 3·5280 | 3·5297 | ·0018 |
| 202 | 23 3·5315 | 3·5333 | 3·5351 | 3·5368 | 3·5386 | 3·5404 | 3·5421 | 3·5439 | 3·5456 | 3·5474 | ·0018 |
| 203 | 3·5492 | 3·5509 | 3·5527 | 3·5544 | 3·5561 | 3·5579 | 3·5596 | 3·5614 | 3·5631 | 3·5648 | ·0017 |
| 204 | 3·5666 | 3·5683 | 3·5700 | 3·5717 | 3·5735 | 3·5752 | 3·5769 | 3·5786 | 3·5803 | 3·5820 | ·0017 |
| 205 | 23 3·5837 | 3·5854 | 3·5871 | 3·5888 | 3·5905 | 3·5922 | 3·5939 | 3·5956 | 3·5973 | 3·5990 | ·0017 |
| 206 | 3·6007 | 3·6024 | 3·6040 | 3·6057 | 3·6074 | 3·6091 | 3·6107 | 3·6124 | 3·6141 | 3·6157 | ·0017 |
| 207 | 3·6174 | 3·6191 | 3·6207 | 3·6224 | 3·6240 | 3·6257 | 3·6273 | 3·6290 | 3·6306 | 3·6323 | ·0016 |
| 208 | 23 3·6339 | 3·6355 | 3·6372 | 3·6388 | 3·6404 | 3·6420 | 3·6437 | 2·6453 | 3·6469 | 3·6485 | ·0016 |
| 209 | 3·6502 | 3·6518 | 3·6534 | 3·6550 | 3·6566 | 3·6582 | 3·6598 | 3·6614 | 3·6630 | 3·6646 | ·0016 |
| 210 | 3·6662 | 3·6678 | 3·6694 | 3·6710 | 3·6726 | 3·6741 | 3·6757 | 3·6773 | 3·6789 | 3·6805 | ·0016 |
| 211 | 23 3·6820 | 3·6836 | 3·6852 | 3·6867 | 3·6883 | 3·6899 | 3·6914 | 3·6930 | 3·6946 | 3·6961 | ·0016 |
| 212 | 3·6977 | 3·6992 | 3·7008 | 3·7023 | 3·7039 | 3·7054 | 3·7070 | 3·7085 | 3·7100 | 3·7116 | ·0015 |
| 213 | 3·7131 | 3·7146 | 3·7162 | 3·7177 | 3·7192 | 3·7207 | 3·7223 | 3·7238 | 3·7253 | 3·7268 | ·0015 |
| 214 | 23 3·7283 | 3·7298 | 3·7313 | 3·7329 | 3·7344 | 3·7359 | 3·7374 | 3·7389 | 3·7404 | 3·7419 | ·0015 |
| 215 | 3·7434 | 3·7448 | 3·7463 | 3·7478 | 3·7493 | 3·7508 | 3·7523 | 3·7538 | 3·7552 | 3·7567 | ·0015 |
| 216 | 3·7582 | 3·7597 | 3·7612 | 3·7626 | 3.7641 | 3·7656 | 3·7670 | 3·7685 | 3·7700 | 3·7714 | ·0015 |
| 217 | 23 3·7729 | 3·7743 | 3·7758 | 3·7772 | 3·7787 | 3·7801 | 3·7816 | 3·7830 | 3·7845 | 3·7859 | ·0014 |
| 218 | 3·7874 | 3·7888 | 3·7902 | 3·7917 | 3·7931 | 3·7945 | 3·7960 | 3·7974 | 3·7988 | 3·8002 | ·0014 |
| 219 | 3·8016 | 3·8031 | 3·8045 | 3·8059 | 3·8073 | 3·8087 | 3·8101 | 3·8115 | 3·8129 | 3·8144 | ·0014 |
| 220 | 23 3·8158 | 3·8172 | 3·8186 | 3·8200 | 3·8214 | 3·8227 | 3·8241 | 3·8255 | 3·8269 | 3·8283 | ·0014 |
| 221 | 3·8297 | 3·8311 | 3·8325 | 3·8338 | 3·8352 | 3·8366 | 3·8380 | 3·8394 | 3·8407 | 3·8421 | ·0014 |
| 222 | 3·8435 | 3·8448 | 3·8462 | 3·8476 | 3·8489 | 3·8503 | 3·8517 | 3·8530 | 3·8544 | 3·8557 | ·0014 |
| 223 | 23 3·8571 | 3·8584 | 3·8598 | 3·8611 | 3·8625 | 3·8638 | 3·8651 | 3·8665 | 3·8678 | 3·8692 | ·0013 |
| 224 | 3·8705 | 3·8718 | 3·8732 | 3·8745 | 3·8758 | 3·8772 | 3·8785 | 3·8798 | 3·8811 | 3·8824 | ·0013 |
| 225 | 3·8838 | 3·8851 | 3·8864 | 3·8877 | 3·8890 | 3·8903 | 3·8916 | 3·8930 | 3·8943 | 3·8956 | ·0013 |
| 226 | 23 3·8969 | 3·8982 | 3·8995 | 3·9008 | 3·9021 | 3·9034 | 3·9047 | 3·9059 | 3·9072 | 3·9085 | ·0013 |
| 227 | 3·9098 | 3·9111 | 3·9124 | 3·9137 | 3·9150 | 3·9162 | 3·9175 | 3·9188 | 3·9201 | 3·9214 | ·0013 |
| 228 | 3·9226 | 3·9239 | 3·9252 | 3·9264 | 3·9277 | 3·9290 | 3·9303 | 3·9315 | 3·9328 | 3·9341 | ·0013 |
| 229 | 23 3·9353 | 3·9366 | 3·9378 | 3·9391 | 3·9404 | 3·9416 | 3·9429 | 3·9441 | 3·9454 | 3·9467 | ·0013 |
| 230 | 3·9479 | 3·9492 | 3·9504 | 3·9517 | 3·9529 | 3·9542 | 3·9554 | 3·9567 | 3·9579 | 3·9592 | ·0013 |
| 231 | 3·9604 | 3·9617 | 3·9629 | 3·9642 | 3·9654 | 3·9667 | 3·9679 | 3·9692 | 3·9704 | 3·9716 | ·0012 |
| 232 | 23 3·9729 | 3·9741 | 3·9754 | 3·9766 | 3·9779 | 3·9791 | 3·9803 | 3·9816 | 3·9828 | 3·9841 | ·0012 |
| 233 | 3·9853 | 3·9866 | 3·9878 | 3·9890 | 3·9903 | 3·9915 | 3·9927 | 3·9940 | 3·9952 | 3·9965 | ·0012 |
| 234 | 3·9977 | 3·9989 | 4·0002 | 4·0014 | 4·0026 | 4·0039 | 4·0051 | 4·0063 | 4·0076 | 4·0088 | ·0012 |
| 235 | 23 4·0100 | 4·0113 | 4·0125 | 4·0137 | 4·0150 | 4·0162 | 4·0174 | 4·0186 | 4·0199 | 4·0211 | ·0012 |
| 236 | 4·0223 | 4·0236 | 4·0248 | 4·0260 | 4·0272 | 4·0284 | 4·0297 | 4·0309 | 4·0321 | 4·0334 | ·0012 |
| 237 | 4·0346 | 4·0358 | 4·0370 | 4·0383 | 4·0395 | 4·0407 | 4·0419 | 4·0131 | 4·0444 | 4·0456 | ·0012 |
| 238 | 23 4·0468 | 4·0480 | 4·0492 | 4·0505 | 4·0517 | 4·0529 | 4·0541 | 0·0553 | 4·0566 | 4·0578 | ·0012 |
| 239 | 4·0590 | 4·0602 | 4·0614 | 4·0626 | 4·0639 | 4·0651 | 4·0663 | 4·0675 | 4·0687 | 4·0699 | ·0012 |
| 240 | 4·0711 | 4·0724 | 4·0736 | 4·0748 | 4·0760 | 4·0772 | 4·0784 | 4·0796 | 4·0809 | 4·0821 | ·0012 |
| 241 | 23 4·0833 | 4·0845 | 4·0857 | 4·0869 | 4·0881 | 4·0893 | 4·0905 | 4·0917 | 4·0930 | 4·0942 | ·0012 |
| 242 | 4·0954 | 4·0966 | 4·0978 | 4·0990 | 4·1002 | 4·1014 | 4·1026 | 4·1038 | 4·1050 | 4·1062 | ·0012 |
| 243 | 4·1074 | 4·1087 | 4·1099 | 4·1111 | 4·1123 | 4·1135 | 4·1147 | 4·1159 | 4·1171 | 4·1183 | ·0012 |
| 244 | 23 4·1195 | 4·1207 | 4·1219 | 4·1231 | 4·1243 | 4·1255 | 4·1267 | 4·1279 | 4·1291 | 4·1303 | ·0012 |
| 245 | 4·1315 | 4·1327 | 4·1339 | 4·1351 | 4·1363 | 4·1375 | 4·1387 | 4·1399 | 4·1411 | 4·1423 | ·0012 |
| 246 | 4·1435 | 4·1447 | 4·1459 | 4·1471 | 4·1483 | 4·1495 | 4·1506 | 4·1518 | 4·1530 | 4·1542 | ·0012 |
| 247 | 23 4·1554 | 4·1566 | 4·1578 | 4·1590 | 4·1602 | 4·1614 | 4·1626 | 4·1638 | 4·1649 | 4·1661 | ·0012 |
| 248 | 4·1673 | 4·1685 | 4·1697 | 4·1709 | 4·1721 | 4·1733 | 4·1744 | 4·1756 | 4·1768 | 4·1780 | ·0012 |
| 249 | 4·1792 | 4·1804 | 4·1815 | 4·1827 | 4·1839 | 4·1851 | 4·1863 | 4·1874 | 4·1886 | 4·1898 | ·0012 |

## TABLE III—*continued.*

### A General Table of Values $\frac{d^2}{w}t$ for Ogival-headed Shot.

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 250 | 23 4·1910 | 4·1922 | 4·1933 | 4·1945 | 4·1957 | 4·1969 | 4·1980 | 4·1992 | 4·2004 | 4·2015 | ·0012 |
| 251 | 4·2027 | 4·2039 | 4·2051 | 4·2062 | 4·2074 | 4·2086 | 4·2097 | 4·2109 | 4·2121 | 4·2132 | ·0012 |
| 252 | 4·2144 | 4·2156 | 4·2167 | 4·2179 | 4·2190 | 4·2202 | 4·2214 | 4·2225 | 4·2237 | 4·2248 | ·0012 |
| 253 | 23 4·2260 | 4·2272 | 4·2283 | 4·2295 | 4·2306 | 4·2318 | 4·2329 | 4·2341 | 4·2352 | 4·2364 | ·0012 |
| 254 | 4·2375 | 4·2387 | 4·2398 | 4·2410 | 4·2421 | 4·2433 | 4·2444 | 4·2455 | 4·2467 | 4·2478 | ·0011 |
| 255 | 4·2490 | 4·2501 | 4·2513 | 4·2524 | 4·2535 | 4·2547 | 4·2558 | 4·2569 | 4·2581 | 4·2592 | ·0011 |
| 256 | 23 4·2603 | 4·2615 | 4·2626 | 4·2637 | 4·2648 | 4·2660 | 4·2671 | 4·2682 | 4·2693 | 4·2705 | ·0011 |
| 257 | 4·2716 | 4·2727 | 4·2738 | 4·2749 | 4·2760 | 4·2772 | 4·2783 | 4·2794 | 4·2805 | 4·2816 | ·0011 |
| 258 | 4·2827 | 4·2838 | 4·2849 | 4·2860 | 4·2871 | 4·2882 | 4·2893 | 4·2904 | 4·2915 | 4·2926 | ·0011 |
| 259 | 23 4·2937 | 4·2948 | 4·2959 | 4·2970 | 4·2981 | 4·2992 | 4·3003 | 4·3014 | 4·3025 | 4·3036 | ·0011 |
| 260 | 4·3046 | 4·3057 | 4·3068 | 4·3079 | 4·3090 | 4·3101 | 4·3111 | 4·3122 | 4·3133 | 4·3144 | ·0011 |
| 261 | 4·3154 | 4·3165 | 4·3176 | 4·3187 | 4·3197 | 4·3208 | 4·3219 | 4·3229 | 4·3240 | 4·3250 | ·0011 |
| 262 | 23 4·3261 | 4·3272 | 4·3282 | 4·3293 | 4·3303 | 4·3314 | 4·3325 | 4·3335 | 4·3346 | 4·3356 | ·0011 |
| 263 | 4·3367 | 4·3377 | 4·3388 | 4·3398 | 4·3409 | 4·3119 | 4·3429 | 4·3440 | 4·3450 | 4·3461 | ·0010 |
| 264 | 4·3471 | 4·3482 | 4·3492 | 4·3502 | 3·3513 | 4·3523 | 4·3533 | 4·3544 | 4·3554 | 4·3564 | ·0010 |
| 265 | 23 4·3574 | 4·3585 | 4·3595 | 4·3605 | 4·3615 | 4·3626 | 4·3636 | 4·3646 | 4·3656 | 4·3667 | ·0010 |
| 266 | 4·3677 | 4·3687 | 4·3697 | 4·3707 | 4·3717 | 4·3728 | 4·3738 | 4·3748 | 4·3758 | 4·3768 | ·0010 |
| 267 | 4·3778 | 4·3788 | 4·3798 | 4·3808 | 4·3818 | 4·3828 | 4·3838 | 4·3848 | 4·3858 | 4·3868 | ·0010 |
| 268 | 23 4·3878 | 4·3888 | 4·3898 | 4·3908 | 4·3918 | 4·3928 | 4·3938 | 4·3948 | 4·3958 | 4·3968 | ·0010 |
| 269 | 4·3977 | 4·3987 | 4·3997 | 4·4007 | 4·4017 | 4·4027 | 4·4036 | 4·4046 | 4·4056 | 4·4066 | ·0010 |
| 270 | 4·4075 | 4·4085 | 4·4095 | 4·4105 | 4·4114 | 4·4124 | 4·4134 | 4·4143 | 4·4153 | 4·4163 | ·0010 |
| 271 | 23 4·4172 | 4·4182 | 4·4192 | 4·4201 | 4·4211 | 4·4220 | 4·4230 | 4·4240 | 4·4249 | 4·4259 | ·0010 |
| 272 | 4·4268 | 4·4278 | 4·4287 | 4·4297 | 4·4307 | 4·4316 | 4·4326 | 4·4335 | 4·4344 | 4·4354 | ·0010 |
| 273 | 4·4363 | 4·4373 | 4·4382 | 4·4392 | 4·4401 | 4·4411 | 4·4420 | 4·4429 | 4·4439 | 4·4448 | ·0009 |
| 274 | 23 4·4457 | 4·4467 | 4·4476 | 4·4485 | 4·4495 | 4·4504 | 4·4513 | 4·4523 | 4·4532 | 4·4541 | ·0009 |
| 275 | 4·4551 | 4·4560 | 4·4569 | 4·4578 | 4·4587 | 4·4597 | 4·4606 | 4·4615 | 4·4624 | 4·4633 | ·0009 |
| 276 | 4·4643 | 4·4652 | 4·4661 | 4·4670 | 4·4679 | 4·4688 | 4·4697 | 4·4706 | 4·4715 | 4·4725 | ·0009 |
| 277 | 23 4·4734 | 4·4743 | 4·4752 | 4·4761 | 4·4770 | 4·4779 | 4·4788 | 4·4797 | 4·4806 | 4·4815 | ·0009 |
| 278 | 4·4824 | 4·4833 | 4·4842 | 4·4850 | 4·4859 | 4·4868 | 4·4877 | 4·4886 | 4·4895 | 4·4904 | .0009 |
| 279 | 4·4913 | 4·4922 | 4·4930 | 4·4939 | 4·4948 | 4·4957 | 4·4966 | 4·4975 | 4·4983 | 4·4992 | ·0009 |
| 280 | 23 4·5001 | 4·5010 | 4·5018 | 4·5027 | 4·5036 | 4·5045 | 4·5053 | 4·5062 | 4·5071 | 4·5080 | ·0009 |
| 281 | 4·5088 | 4·5097 | 4·5105 | 4·5114 | 4·5123 | 4·5131 | 4·5140 | 4·5148 | 4·5157 | 4·5166 | ·0009 |
| 282 | 4·5174 | 4·5183 | 4·5191 | 4·5200 | 4·5208 | 4·5217 | 4·5226 | 4·5234 | 4·5243 | 4·5251 | ·0009 |
| 283 | 23 4·5260 | 4·5268 | 4·5277 | 4·5285 | 4·5293 | 4·5302 | 4·5310 | 4·5319 | 4·5327 | 4·5336 | ·0008 |
| 284 | 4·5344 | 4·5352 | 4·5361 | 4·5369 | 4·5378 | 4·5386 | 4·5394 | 4·5403 | 4·5411 | 4·5419 | ·0008 |
| 285 | 4·5427 | 4·5436 | 4·5444 | 4·5452 | 4·5461 | 4·5469 | 4·5477 | 4·5485 | 4·5494 | 4·5502 | ·0008 |
| 286 | 23 4·5510 | 4·5518 | 4·5527 | 4·5535 | 4·5543 | 4·5551 | 4·5559 | 4·5567 | 4·5576 | 4·5584 | ·0008 |
| 287 | 4·5592 | 4·5600 | 4·5608 | 4·5616 | 4·5624 | 4·5632 | 4·5641 | 4·5648 | 4·5657 | 4·5665 | ·0008 |
| 288 | 4·5673 | 4·5681 | 4·5689 | 4·5697 | 4·5705 | 4·5713 | 4·5721 | 4·5729 | 4·5737 | 4·5745 | ·0008 |
| 289 | 23 4·5753 | 4·5761 | 4·5769 | 4·5777 | 4·5785 | 4·5793 | 4·5800 | 4·5808 | 4·5816 | 4·5824 | ·0008 |
| 290 | 4·5832 | | | | | | | | | | |

# Table IV.

## A General Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

| $v$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 10 | 1066 | 1238 | 1409 | 1578 | 1745 | 1910 | 2074 | 2236 | 2397 | 2557 | 166 |
| 11 | 2715 | 2871 | 3026 | 3180 | 3333 | 3484 | 3633 | 3782 | 3929 | 4075 | 151 |
| 12 | 4220 | 4363 | 4506 | 4647 | 4787 | 4926 | 5064 | 5200 | 5336 | 5471 | 139 |
| 13 | 5604 | 5737 | 5866 | 5999 | 6129 | 6257 | 6385 | 6511 | 6637 | 6762 | 129 |
| 14 | 6886 | 7009 | 7132 | 7253 | 7373 | 7493 | 7612 | 7730 | 7847 | 7964 | 120 |
| 15 | 8079 | 8194 | 8309 | 8422 | 8535 | 8647 | 8758 | 8868 | 8978 | 9087 | 112 |
| 16 | 9196 | 9304 | 9411 | 9517 | 9623 | 9728 | 9833 | 9937 | 10040 | 10142 | 105 |
| 17 | 10244 | 10346 | 10447 | 10546 | 10645 | 10743 | 10841 | 10939 | 11037 | 11134 | 98 |
| 18 | 11230 | 11326 | 11421 | 11516 | 11610 | 11704 | 11797 | 11890 | 11982 | 12074 | 94 |
| 19 | 12165 | 12256 | 12346 | 12436 | 12525 | 12614 | 12703 | 12791 | 12878 | 12966 | 89 |
| 20 | 13052 | 13139 | 13224 | 13310 | 13395 | 13480 | 13564 | 13648 | 13731 | 13814 | 85 |
| 21 | 13896 | 13979 | 14060 | 14142 | 14223 | 14303 | 14384 | 14463 | 14543 | 14622 | 81 |
| 22 | 14701 | 14779 | 14857 | 14935 | 15013 | 15090 | 15167 | 15244 | 15319 | 15395 | 77 |
| 23 | 15470 | 15545 | 15620 | 15694 | 15768 | 15842 | 15916 | 15989 | 16061 | 16134 | 74 |
| 24 | 16206 | 16278 | 16350 | 16421 | 16492 | 16563 | 16633 | 16703 | 16773 | 16843 | 71 |
| 25 | 1 6912·1 | 6981·2 | 7050·0 | 7118·5 | 7186·7 | 7254·7 | 7322·4 | 7389·8 | 7457·0 | 7523·9 | 68·0 |
| 26 | 7590·6 | 7657·0 | 7723·2 | 7789·1 | 7854·7 | 7920·1 | 7985·3 | 8050·2 | 8114·8 | 8179·3 | 65·4 |
| 27 | 8243·5 | 8307·5 | 8371·2 | 8434·7 | 8498·0 | 8561·0 | 8623·9 | 8686·4 | 8748·8 | 8810·9 | 63·0 |
| 28 | 1 8872·8 | 8934·5 | 8996·0 | 9057·2 | 9118·3 | 9179·1 | 9239·7 | 9300·1 | 9360·3 | 9420·3 | 60·8 |
| 29 | 9480·0 | 9539·6 | 9598·9 | 9658·1 | 9717·0 | 9775·8 | 9834·3 | 9892·6 | 9950·8 | *0008·7 | 58·7 |
| 30 | 2 0066·5 | 0124·0 | 0181·4 | 0238·5 | 0295·5 | 0352·3 | 0409·0 | 0465·4 | 0521·7 | 0577·7 | 56·8 |
| 31 | 2 0633·6 | 0689·3 | 0744·8 | 0800·1 | 0855·3 | 0910·2 | 0965·0 | 1019·6 | 1074·0 | 1128·3 | 55·0 |
| 32 | 1182·4 | 1236·3 | 1290·0 | 1343·5 | 1396·9 | 1450·2 | 1503·2 | 1556·1 | 1608·8 | 1661·4 | 53·2 |
| 33 | 1713·8 | 1766·0 | 1818·1 | 1870·0 | 1921·7 | 1973·3 | 2024·7 | 2076·0 | 2127·1 | 2178·1 | 51·6 |
| 34 | 2 2228·9 | 2279·6 | 2330·0 | 2380·4 | 2430·6 | 2480·6 | 2530·5 | 2580·2 | 2629·7 | 2679·1 | 50·0 |
| 35 | 2728·4 | 2777·5 | 2826·4 | 2875·2 | 2923·8 | 2972·3 | 3020·7 | 3068·8 | 3116·9 | 3164·7 | 48·5 |
| 36 | 3212·5 | 3260·1 | 3307·5 | 3354·8 | 3402·0 | 3449·0 | 3495·9 | 3542·6 | 3589·2 | 3635·6 | 47·0 |
| 37 | 2 3682·0 | 3728·1 | 3774·2 | 3820·0 | 3865·8 | 3911·4 | 3956·9 | 4002·2 | 4047·4 | 4092·5 | 45·6 |
| 38 | 4137·4 | 4182·2 | 4226·8 | 4271·4 | 4315·7 | 4360·0 | 4404·1 | 4448·1 | 4491·9 | 4535·7 | 44·3 |
| 39 | 4579·2 | 4622·7 | 4666·0 | 4709·2 | 4752·3 | 4795·2 | 4838·1 | 4880·8 | 4923·3 | 4965·7 | 42·9 |
| 40 | 2 5008·0 | 5050·2 | 5092·3 | 5134·2 | 5176·0 | 5217·6 | 5259·2 | 5300·6 | 5341·9 | 5383·0 | 41·7 |
| 41 | 5424·0 | 5464·9 | 5505·7 | 5546·4 | 5586·9 | 5627·3 | 5667·6 | 5707·8 | 5747·8 | 5787·8 | 40·4 |
| 42 | 5827·6 | 5867·3 | 5906·9 | 5946·4 | 5985·8 | 6025·0 | 6064·2 | 6103·3 | 6142·2 | 6181·0 | 39·3 |
| 43 | 2 6219·8 | 6258·4 | 6296·9 | 6335·3 | 6373·6 | 6411·8 | 6419·9 | 6487·9 | 6525·8 | 6563·6 | 38·2 |
| 44 | 6601·3 | 6638·9 | 6676·4 | 6713·7 | 6751·0 | 6788·2 | 6825·3 | 6862·3 | 6899·3 | 6936·1 | 37·2 |
| 45 | 6972·8 | 7009·4 | 7046·0 | 7082·4 | 7118·8 | 7155·0 | 7191·2 | 7227·3 | 7263·3 | 7299·2 | 36·3 |
| 46 | 2 7335·1 | 7370·8 | 7406·5 | 7442·1 | 7477·6 | 7513·0 | 7548·3 | 7583·6 | 7618·8 | 7653·9 | 35·4 |
| 47 | 7688·9 | 7723·8 | 7758·7 | 7793·5 | 7828·2 | 7862·8 | 7897·3 | 7931·8 | 7966·2 | 8000·5 | 34·6 |
| 48 | 8034·7 | 8068·9 | 8103·0 | 8137·0 | 8170·9 | 8204·8 | 8238·6 | 8272·3 | 8305·9 | 8339·5 | 33·9 |
| 49 | 2 8373·0 | 8406·5 | 8439·8 | 8473·1 | 8506·4 | 8539·5 | 8572·6 | 8605·6 | 8638·6 | 8671·5 | 33·2 |
| 50 | 8704·3 | 8737·1 | 8769·8 | 8802·4 | 8835·0 | 8867·5 | 8900·0 | 8932·3 | 8964·7 | 8996·9 | 32·5 |
| 51 | 9029·1 | 9061·2 | 9093·2 | 9125·2 | 9157·1 | 9189·0 | 9220·8 | 9252·5 | 9284·2 | 9315·8 | 31·9 |
| 52 | 2 9347·3 | 9378·8 | 9410·3 | 9441·6 | 9472·9 | 9504·2 | 9535·4 | 9566·5 | 9597·6 | 9628·7 | 31·3 |
| 53 | 9659·6 | 9690·6 | 9721·4 | 9752·2 | 9783·0 | 9813·7 | 9844·3 | 9874·9 | 9905·4 | 9935·9 | 30·7 |
| 54 | 9966·3 | 9996·7 | *0027·0 | *0057·3 | *0087·5 | *0117·7 | *0147·8 | *0177·8 | *0207·8 | *0237·8 | 30·2 |
| 55 | 3 0267·6 | 0297·5 | 0327·3 | 0357·0 | 0386·7 | 0416·3 | 0445·9 | 0475·4 | 0504·9 | 0534·3 | 29·6 |
| 56 | 0563·6 | 0592·9 | 0622·2 | 0651·4 | 0680·6 | 0709·7 | 0738·7 | 0767·7 | 0796·7 | 0825·6 | 29·1 |
| 57 | 0854·5 | 0883·3 | 0912·1 | 0940·9 | 0969·6 | 0998·2 | 1026·8 | 1055·4 | 1083·9 | 1112·4 | 28·6 |
| 58 | 3 1140·8 | 1169·2 | 1197·6 | 1226·0 | 1254·3 | 1282·5 | 1310·8 | 1339·0 | 1367·1 | 1395·2 | 28·3 |
| 59 | 1423·3 | 1451·3 | 1479·3 | 1507·3 | 1535·2 | 1563·0 | 1590·9 | 1618·7 | 1646·4 | 1674·2 | 27·9 |
| 60 | 1701·8 | 1729·5 | 1757·1 | 1784·6 | 1812·2 | 1839·6 | 1867·1 | 1894·5 | 1921·9 | 1949·2 | 27·5 |
| 61 | 3 1976·5 | 2003·7 | 2031·0 | 2058·1 | 2085·3 | 2112·4 | 2139·4 | 2166·4 | 2193·4 | 2220·4 | 27·1 |
| 62 | 2247·3 | 2274·2 | 2301·0 | 2327·8 | 2354·5 | 2381·3 | 2407·9 | 2434·6 | 2461·2 | 2487·7 | 26·7 |
| 63 | 2514·3 | 2540·8 | 2567·2 | 2593·6 | 2620·0 | 2646·3 | 2672·6 | 2698·9 | 2725·1 | 2751·3 | 26·3 |
| 64 | 3 2777·5 | 2803·6 | 2829·7 | 2855·7 | 2881·7 | 2907·7 | 2933·7 | 2959·6 | 2985·4 | 3011·2 | 26·0 |
| 65 | 3037·0 | 3062·8 | 3088·5 | 3114·2 | 3139·8 | 3165·4 | 3191·0 | 3216·5 | 3242·0 | 3267·4 | 25·6 |
| 66 | 3292·8 | 3318·2 | 3343·5 | 3368·8 | 3394·1 | 3419·3 | 3444·5 | 3469·6 | 3494·7 | 3519·8 | 25·2 |
| 67 | 3 3544·8 | 3569·8 | 3594·8 | 3619·8 | 3644·7 | 3669·5 | 3694·3 | 3719·1 | 3743·9 | 3768·6 | 24·8 |
| 68 | 3793·3 | 3818·0 | 3842·6 | 3867·2 | 3891·7 | 3916·2 | 3940·7 | 3965·2 | 3989·6 | 4014·0 | 24·5 |
| 69 | 4038·4 | 4062·7 | 4087·0 | 4111·3 | 4135·6 | 4159·8 | 4184·0 | 4208·1 | 4232·2 | 4256·3 | 24·2 |

## Table IV.—*continued.*

### A General Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 70 | 3 4280·4 | 4304·5 | 4328·5 | 4352·4 | 4376·4 | 4400·3 | 4424·1 | 4448·0 | 4471·8 | 4495·5 | 23·9 |
| 71 | 4519·3 | 4543·0 | 4566·6 | 4590·2 | 4613·8 | 4637·4 | 4660·9 | 4684·4 | 4707·8 | 4731·3 | 23·5 |
| 72 | 4754·7 | 4777·9 | 4801·3 | 4824·6 | 4847·9 | 4871·1 | 4894·2 | 4917·4 | 4940·5 | 4963·6 | 23·2 |
| 73 | 3 4986·6 | 5009·6 | 5032·6 | 5055·5 | 5078·4 | 5101·3 | 5124·1 | 5146·9 | 5169·6 | 5192·4 | 22·8 |
| 74 | 5215·1 | 5237·7 | 5260·3 | 5282·9 | 5305·5 | 5328·0 | 5350·5 | 5373·0 | 5395·4 | 5417·8 | 22·5 |
| 75 | 5440·2 | 5462·5 | 5484·8 | 5507·1 | 5529·3 | 5551·5 | 5573·7 | 5595·8 | 5617·9 | 5640·0 | 22·2 |
| 76 | 3 5662·1 | 5684·1 | 5706·0 | 5728·0 | 5749·9 | 5771·7 | 5793·5 | 5815·3 | 5837·0 | 5858·7 | 21·8 |
| 77 | 5880·4 | 5902·0 | 5923·6 | 5945·1 | 5966·6 | 5988·1 | 6009·5 | 6030·9 | 6052·2 | 6073·6 | 21·5 |
| 78 | 6094·8 | 6116·1 | 6137·3 | 6158·4 | 6179·6 | 6200·7 | 6221·7 | 6242·7 | 6263·7 | 6284·6 | 21·1 |
| 79 | 3 6305·5 | 6326·4 | 6347·2 | 6368·0 | 6388·8 | 6409·5 | 6430·2 | 6450·8 | 6471·4 | 6492·0 | 20·7 |
| 80 | 6512·6 | 6533·1 | 6553·6 | 6574·0 | 6594·4 | 6614·8 | 6635·1 | 6655·4 | 6675·7 | 6695·9 | 20·4 |
| 81 | 6716·1 | 6736·3 | 6756·4 | 6776·5 | 6796·5 | 6816·5 | 6836·5 | 6856·4 | 6876·3 | 6896·1 | 20·0 |
| 82 | 3 6916·0 | 6935·7 | 6955·5 | 6975·1 | 6994·8 | 7014·4 | 7033·9 | 7053·4 | 7072·9 | 7092·3 | 19·6 |
| 83 | 7111·7 | 7131·0 | 7150·3 | 7169·6 | 7188·8 | 7207·9 | 7227·1 | 7246·1 | 7265·2 | 7284·1 | 19·1 |
| 84 | 7303·1 | 7322·0 | 7340·8 | 7359·6 | 7378·4 | 7397·1 | 7415·8 | 7434·4 | 7453·0 | 7471·5 | 18·7 |
| 85 | 3 7490·0 | 7508·5 | 7526·9 | 7545·3 | 7563·6 | 7581·8 | 7600·0 | 7618·2 | 7636·3 | 7654·4 | 18·2 |
| 86 | 7672·4 | 7690·5 | 7708·4 | 7726·4 | 7744·2 | 7762·0 | 7779·9 | 7797·6 | 7815·4 | 7833·0 | 17·8 |
| 87 | 7850·6 | 7868·2 | 7885·8 | 7903·3 | 7920·8 | 7938·2 | 7955·6 | 7973·0 | 7990·3 | 8007·6 | 17·4 |
| 88 | 3 8024·8 | 8042·0 | 8059·2 | 8076·3 | 8093·4 | 8110·4 | 8127·4 | 8144·4 | 8161·3 | 8178·2 | 17·0 |
| 89 | 8195·0 | 8211·9 | 8228·6 | 8245·4 | 8262·1 | 8278·7 | 8295·4 | 8312·0 | 8328·5 | 8345·0 | 16·6 |
| 90 | 8361·5 | 8377·9 | 8394·3 | 8410·7 | 8427·0 | 8443·3 | 8459·6 | 8475·8 | 8492·0 | 8508·2 | 16·3 |
| 91 | 3 8524·3 | 8540·4 | 8556·4 | 8572·4 | 8588·4 | 8604·3 | 8620·3 | 8636·1 | 8652·0 | 8667·8 | 15·9 |
| 92 | 8683·5 | 8699·3 | 8715·0 | 8730·7 | 8746·3 | 8761·9 | 8777·5 | 8793·0 | 8808·5 | 8824·0 | 15·6 |
| 93 | 8839·4 | 8854·8 | 8870·2 | 8885·5 | 8900·8 | 8916·1 | 8931·3 | 8946·5 | 8961·7 | 8976·8 | 15·3 |
| 94 | 3 8991·9 | 9007·0 | 9022·0 | 9037·0 | 9052·0 | 9066·9 | 9081·9 | 9096·7 | 9111·6 | 9126·4 | 15·0 |
| 95 | 9141·2 | 9156·0 | 9170·7 | 9185·4 | 9200·1 | 9214·7 | 9229·3 | 9243·9 | 9258·4 | 9272·9 | 14·6 |
| 96 | 9287·4 | 9301·9 | 9316·3 | 9330·7 | 9345·0 | 9359·4 | 9373·7 | 9387·9 | 9402·2 | 9416·4 | 14·3 |
| 97 | 3 9430·6 | 9444·7 | 9458·9 | 9473·0 | 9487·0 | 9501·1 | 9515·1 | 9529·1 | 9543·0 | 9557·0 | 14·0 |
| 98 | 9570·8 | 9584·7 | 9598·6 | 9612·4 | 9626·1 | 9639·9 | 9653·6 | 9667·3 | 9681·0 | 9694·6 | 13·7 |
| 99 | 9708·3 | 9721·9 | 9735·4 | 9749·0 | 9762·5 | 9775·9 | 9789·4 | 9802·8 | 9816·2 | 9829·6 | 13·5 |
| 100 | 3 9842·9 | 9856·3 | 9869·6 | 9882·9 | 9896·1 | 9909·3 | 9922·5 | 9935·3 | 9948·8 | 9961·9 | 13·2 |
| 101 | 9975·0 | 9988·1 | *0001·1 | *0014·1 | *0027·1 | *0040·0 | *0052·9 | *0065·8 | *0078·7 | *0091·5 | 12·9 |
| 102 | 4 0104·3 | 0117·1 | 0129·8 | 0142·5 | 0155·2 | 0167·8 | 0180·4 | 0192·9 | 0205·4 | 0217·8 | 12·6 |
| 103 | 4 0230·1 | 0242·4 | 0254·6 | 0266·8 | 0278·8 | 0290·8 | 0302·7 | 0314·5 | 0326·2 | 0337·8 | 11·9 |
| 104 | 0349·4 | 0360·8 | 0372·2 | 0383·4 | 0394·5 | 0405·6 | 0416·5 | 0427·3 | 0438·1 | 0448·7 | 11·0 |
| 105 | 0459·2 | 0469·6 | 0479·9 | 0490·0 | 0500·1 | 0510·1 | 0520·0 | 0529·8 | 0539·5 | 0549·2 | 9·9 |
| 106 | 4 0558·7 | 0568·2 | 0577·6 | 0586·9 | 6596·2 | 0605·4 | 0614·5 | 0523·6 | 0632·6 | 0641·6 | 9·2 |
| 107 | 0650·5 | 0659·3 | 0668·1 | 0676·9 | 0685·6 | 0694·2 | 0702·8 | 0711·4 | 0719·9 | 0728·4 | 8·6 |
| 108 | 0736·8 | 0745·2 | 0753·6 | 0761·9 | 0770·2 | 0778·4 | 0786·6 | 0794·8 | 0802·9 | 0811·0 | 8·2 |
| 109 | 4 0819·0 | 0827·1 | 0835·0 | 0843·0 | 0850·9 | 0858·9 | 0866·7 | 0874·6 | 0882·4 | 0890·2 | 7·9 |
| 110 | 0897·9 | 0905·7 | 0913·4 | 0921·1 | 0928·7 | 0936·4 | 0944·0 | 0951·5 | 0959·1 | 0966·6 | 7·6 |
| 111 | 0974·2 | 0981·6 | 0989·1 | 0996·6 | 1004·0 | 1011·4 | 1018·8 | 1026·2 | 1033·5 | 1040·9 | 7·4 |
| 112 | 4 1048·2 | 1055·5 | 1062·8 | 1070·0 | 1077·3 | 1084·5 | 1091·7 | 1099·0 | 1106·1 | 1113·3 | 7·2 |
| 113 | 1120·5 | 1127·6 | 1134·8 | 1141·9 | 1149·0 | 1156·1 | 1163·2 | 1170·2 | 1177·3 | 1184·4 | 7·1 |
| 114 | 1191·4 | 1198·4 | 1205·4 | 1212·4 | 1219·4 | 1226·4 | 1233·3 | 1240·3 | 1247·2 | 1254·1 | 6·9 |
| 115 | 4 1261·0 | 1267·9 | 1274·8 | 1281·7 | 1288·6 | 1295·4 | 1302·3 | 1309·1 | 1315·9 | 1322·7 | 6·8 |
| 116 | 1329·5 | 1336·3 | 1343·1 | 1349·8 | 1356·6 | 1363·3 | 1370·0 | 1376·7 | 1383·4 | 1390·1 | 6·7 |
| 117 | 1396·8 | 1403·5 | 1410·1 | 1416·8 | 1423·4 | 1430·0 | 1436·6 | 1443·2 | 1449·8 | 1456·4 | 6·6 |
| 118 | 4 1462·9 | 1469·5 | 1476·0 | 1482·6 | 1489·1 | 1495·6 | 1502·1 | 1508·6 | 1515·1 | 1521·5 | 6·5 |
| 119 | 1528·0 | 1534·4 | 1540·9 | 1547·3 | 1553·7 | 1560·1 | 1566·5 | 1572·9 | 1579·2 | 1585·6 | 6·4 |
| 120 | 1591·9 | 1598·3 | 1604·6 | 1610·9 | 1617·2 | 1623·5 | 1629·8 | 1636·1 | 1642·3 | 1648·6 | 6·3 |
| 121 | 4 1654·8 | 1661·1 | 1667·3 | 1673·5 | 1679·7 | 1685·9 | 1692·1 | 1698·2 | 1704·4 | 1710·5 | 6·2 |
| 122 | 1716·7 | 1722·8 | 1728·9 | 1735·0 | 1741·1 | 1747·2 | 1753·3 | 1759·4 | 1765·4 | 1771·5 | 6·1 |
| 123 | 1777·5 | 1783·6 | 1789·6 | 1795·6 | 1801·6 | 1807·6 | 1813·6 | 1819·6 | 1825·6 | 1831·5 | 6·0 |
| 124 | 4 1837·5 | 1843·4 | 1849·4 | 1855·3 | 1861·2 | 1867·1 | 1873·0 | 1878·9 | 1884·8 | 1890·6 | 5·9 |
| 125 | 1896·5 | 1902·3 | 1908·2 | 1914·0 | 1919·8 | 1925·6 | 1931·5 | 1937·3 | 1943·0 | 1948·8 | 5·8 |
| 126 | 1954·6 | 1960·4 | 1966·1 | 1971·9 | 1977·6 | 1983·3 | 1989·0 | 1994·8 | 2000·5 | 2006·2 | 5·7 |
| 127 | 4 2011·8 | 2017·5 | 2023·2 | 2028·9 | 2034·5 | 2040·2 | 2045·8 | 2051·4 | 2057·0 | 2062·7 | 5·6 |
| 128 | 2068·3 | 2073·9 | 2079·5 | 2085·0 | 2090·6 | 2096·2 | 2101·8 | 2107·3 | 2112·9 | 2118·4 | 5·6 |
| 129 | 2123·9 | 2129·4 | 2135·0 | 2140·5 | 2146·0 | 2151·5 | 2157·0 | 2162·4 | 2167·9 | 2173·4 | 5·5 |

## Table IV.—*continued*.

### A General Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 130 | 4 2178·8 | 2184·3 | 2189·7 | 2195·1 | 2200·6 | 2206·0 | 2211·4 | 2216·8 | 2222·2 | 2227·6 | 5·4 |
| 131 | 2233·0 | 2238·4 | 2243·7 | 2249·1 | 2254·5 | 2259·8 | 2265·1 | 2270·5 | 2275·8 | 2281·1 | 5·3 |
| 132 | 2286·4 | 2291·8 | 2297·1 | 2302·4 | 2307·6 | 2312·9 | 2318·2 | 2323·5 | 2328·7 | 2334·0 | 5·3 |
| 133 | 4 2339·2 | 2344·5 | 2349·7 | 2355·0 | 2360·2 | 2365·4 | 2370·6 | 2375·8 | 2381·0 | 2386·2 | 5·2 |
| 134 | 2391·4 | 2396·6 | 2401·8 | 2406·9 | 2412·1 | 2417·3 | 2422·4 | 2427·6 | 2452·7 | 2437·8 | 5·2 |
| 135 | 2443·0 | 2448·1 | 2453·2 | 2458·3 | 2463·4 | 2468·5 | 2473·6 | 2478·7 | 2483·8 | 2488·9 | 5·1 |
| 136 | 4 2493·9 | 2499·0 | 2504·1 | 2509·1 | 2514·2 | 2519·2 | 2524·3 | 2529·3 | 2534·3 | 2539·4 | 5·0 |
| 137 | 2544·4 | 2519·4 | 2554·4 | 2559·4 | 2564·4 | 2569·4 | 2574·4 | 2579·4 | 2584·3 | 2589·3 | 5·0 |
| 138 | 2594·3 | 2599·2 | 2604·2 | 2609·1 | 2614·1 | 2619·0 | 2624·0 | 2628·9 | 2633·8 | 2638·8 | 4·9 |
| 139 | 4 2643·7 | 2648·6 | 2653·5 | 2658·4 | 2663·3 | 2668·2 | 2673·1 | 2678·0 | 2682·9 | 2687·8 | 4·9 |
| 140 | 2692·6 | 2697·5 | 2702·4 | 2707·2 | 2712·1 | 2717·0 | 2721·8 | 2726·7 | 2731·5 | 2736·3 | 4·9 |
| 141 | 2741·2 | 2746·0 | 2750·8 | 2755·7 | 2760·5 | 2765·3 | 2770·1 | 2774·9 | 2779·7 | 2784·5 | 4·8 |
| 142 | 4 2789·3 | 2794·1 | 2798·9 | 2803·7 | 2808·5 | 2813·2 | 2818·0 | 2822·8 | 2827·5 | 2832·3 | 4·8 |
| 143 | 2837·1 | 2841·8 | 2846·6 | 2851·3 | 2856·0 | 2860·8 | 2865·5 | 2870·2 | 2875·0 | 2879·7 | 4·7 |
| 144 | 2884·4 | 2889·1 | 2893·8 | 2898·6 | 2903·3 | 2908·0 | 2912·7 | 2917·4 | 2922·1 | 2926·7 | 4·7 |
| 145 | 4 2931·4 | 2936·1 | 2940·8 | 2945·5 | 2950·1 | 2954·8 | 2959·5 | 2964·1 | 2968·8 | 2973·5 | 4·7 |
| 146 | 2978·1 | 2982·8 | 2987·4 | 2992·1 | 2996·7 | 3001·3 | 3006·0 | 3010·6 | 3015·2 | 3019·9 | 4·6 |
| 147 | 3024·5 | 3029·1 | 3033·7 | 3038·4 | 3043·0 | 3047·6 | 3052·2 | 3056·8 | 3061·4 | 3066·0 | 4·6 |
| 148 | 4 3070·6 | 3075·2 | 3079·8 | 3084·4 | 3089·0 | 3093·5 | 3098·1 | 3102·7 | 3107·3 | 3111·8 | 4·6 |
| 149 | 3116·4 | 3121·0 | 3125·6 | 3130·1 | 3134·7 | 3139·2 | 3143·8 | 3148·3 | 3152·9 | 3157·4 | 4·6 |
| 150 | 3162·0 | 3166·5 | 3171·0 | 3175·6 | 3180·1 | 3184·6 | 3189·2 | 3193·7 | 3198·2 | 3202·7 | 4·5 |
| 151 | 4 3207·2 | 3211·8 | 3216·3 | 3220·8 | 3225·3 | 3229·8 | 3234·3 | 3238·8 | 3243·3 | 3247·8 | 4·5 |
| 152 | 3252·3 | 3256·8 | 3261·3 | 3265·8 | 3270·3 | 3274·8 | 3279·3 | 3283·8 | 3288·3 | 3292·8 | 4·5 |
| 153 | 3297·2 | 3301·7 | 3306·2 | 3310·6 | 3315·1 | 3319·6 | 3324·1 | 3328·5 | 3333·0 | 3337·5 | 4·5 |
| 154 | 4 3342·0 | 3346·4 | 3350·9 | 3355·3 | 3359·8 | 3364·3 | 3368·7 | 3373·2 | 3377·6 | 3382·1 | 4·5 |
| 155 | 3386·5 | 3391·0 | 3395·4 | 3399·9 | 3404·3 | 3408·7 | 3413·2 | 3417·6 | 3422·0 | 3426·5 | 4·4 |
| 156 | 3430·9 | 3435·3 | 3439·8 | 3444·2 | 3448·6 | 3453·0 | 3457·4 | 3461·9 | 3466·3 | 3470·7 | 4·4 |
| 157 | 4 3475·1 | 3479·5 | 3483·9 | 3488·3 | 3492·7 | 3497·1 | 3501·5 | 3505·9 | 3510·3 | 3514·7 | 4·4 |
| 158 | 3519·1 | 3523·5 | 3527·9 | 3532·3 | 3536·7 | 3541·1 | 3545·4 | 3549·8 | 3554·2 | 3558·6 | 4·4 |
| 159 | 3563·0 | 3567·3 | 3571·7 | 3576·1 | 3580·4 | 3584·8 | 3589·1 | 3593·5 | 3597·9 | 3602·2 | 4·4 |
| 160 | 4 3606·6 | 3610·9 | 3615·3 | 3619·6 | 3624·0 | 3628·3 | 3632·6 | 3637·0 | 3641·3 | 3645·7 | 4·3 |
| 161 | 3650·0 | 3654·3 | 3658·7 | 3663·0 | 3667·3 | 3671·6 | 3676·0 | 3680·3 | 3684·6 | 3688·9 | 4·3 |
| 162 | 3693·3 | 3697·6 | 3701·9 | 3706·1 | 3710·5 | 3714·8 | 3719·1 | 3723·4 | 3727·7 | 3732·0 | 4·3 |
| 163 | 4 3736·3 | 3740·6 | 3744·9 | 3749·2 | 3753·5 | 3757·8 | 3762·1 | 3766·4 | 3770·6 | 3774·9 | 4·3 |
| 164 | 3779·2 | 3783·5 | 3787·8 | 3792·0 | 3796·3 | 3800·6 | 3804·9 | 3809·1 | 3813·4 | 3817·6 | 4·3 |
| 165 | 3821·9 | 3826·2 | 3830·4 | 3834·7 | 3838·9 | 3843·2 | 3847·4 | 3851·7 | 3855·9 | 3860·2 | 4·3 |
| 166 | 4 3864·4 | 3868·7 | 3872·9 | 3877·2 | 3881·4 | 3885·6 | 3889·9 | 3894·1 | 3898·3 | 3902·5 | 4·2 |
| 167 | 3906·8 | 3911·0 | 3915·2 | 3919·5 | 3923·7 | 3927·9 | 3932·1 | 3936·3 | 3940·5 | 3944·7 | 4·2 |
| 168 | 3949·0 | 3953·2 | 3957·4 | 3961·6 | 3965·8 | 3970·0 | 3974·2 | 3978·4 | 3982·6 | 3986·7 | 4·2 |
| 169 | 4 3990·9 | 3995·1 | 3999·3 | 4003·5 | 4007·7 | 4011·9 | 4016·0 | 4020·2 | 4024·4 | 4028·6 | 4·2 |
| 170 | 4032·7 | 4036·9 | 4041·1 | 4045·2 | 4049·4 | 4053·6 | 4057·7 | 4061·9 | 4066·0 | 4070·2 | 4·2 |
| 171 | 4074·3 | 4078·5 | 4082·6 | 4086·8 | 4090·9 | 4095·1 | 4099·2 | 4103·3 | 4107·5 | 4111·6 | 4·1 |
| 172 | 4 4115·7 | 4119·9 | 4124·0 | 4128·1 | 4132·3 | 4136·4 | 4140·5 | 4144·6 | 4148·7 | 4152·9 | 4·1 |
| 173 | 4157·0 | 4161·1 | 4165·2 | 4169·3 | 4173·4 | 4177·5 | 4181·6 | 4185·7 | 4189·8 | 4193·9 | 4·1 |
| 174 | 4198·0 | 4202·1 | 4206·2 | 4210·3 | 4214·4 | 4218·5 | 4222·6 | 4226·7 | 4230·8 | 4234·8 | 4·1 |
| 175 | 4 4238·9 | 4243·0 | 4247·1 | 4251·2 | 4255·3 | 4259·3 | 4263·4 | 4267·5 | 4271·5 | 4275·6 | 4·1 |
| 176 | 4279·6 | 4283·7 | 4287·8 | 4291·8 | 4295·9 | 4300·0 | 4304·0 | 4308·0 | 4312·1 | 4316·1 | 4·1 |
| 177 | 4320·2 | 4324·2 | 4328·3 | 4332·3 | 4336·4 | 4340·4 | 4344·4 | 4348·5 | 4352·5 | 4356·5 | 4·0 |
| 178 | 4 4360·5 | 4364·6 | 4368·6 | 4372·6 | 4376·6 | 4380·7 | 4384·7 | 4388·7 | 4392·7 | 4396·7 | 4·0 |
| 179 | 4400·7 | 4404·7 | 4408·8 | 4412·8 | 4416·8 | 4420·8 | 4424·8 | 4428·8 | 4432·8 | 4436·8 | 4·0 |
| 180 | 4440·8 | 4444·7 | 4448·7 | 4452·7 | 4456·7 | 4460·7 | 4464·7 | 4468·7 | 4472·6 | 4476·6 | 4·0 |
| 181 | 4 4480·6 | 4484·6 | 4488·5 | 4492·5 | 4496·5 | 4500·5 | 4504·4 | 4508·4 | 4512·4 | 4516·3 | 4·0 |
| 182 | 4520·3 | 4524·2 | 4528·2 | 4532·2 | 4536·1 | 4540·1 | 4544·0 | 4548·0 | 4551·9 | 4555·9 | 4·0 |
| 183 | 4559·8 | 4563·7 | 4567·7 | 4571·6 | 4575·6 | 4579·5 | 4583·4 | 4587·4 | 4591·3 | 4595·2 | 3·9 |
| 184 | 4 4599·2 | 4603·1 | 4607·0 | 4610·9 | 4614·9 | 4618·8 | 4622·7 | 4626·6 | 4630·5 | 4634·4 | 3·9 |
| 185 | 4638·4 | 4642·3 | 4646·2 | 4650·1 | 4654·0 | 4657·9 | 4661·8 | 4665·7 | 4669·6 | 4673·5 | 3·9 |
| 186 | 4677·4 | 4681·3 | 4685·2 | 4689·1 | 4693·0 | 4696·9 | 4700·8 | 4704·6 | 4708·5 | 4712·4 | 3·9 |
| 187 | 4 4716·3 | 4720·2 | 4724·1 | 4727·9 | 4731·8 | 4735·7 | 4739·6 | 4743·4 | 4747·3 | 4751·2 | 3·9 |
| 188 | 4755·0 | 4758·9 | 4762·8 | 4766·7 | 4770·5 | 4774·4 | 4778·2 | 4782·1 | 4786·0 | 4789·8 | 3·9 |
| 189 | 4793·7 | 4797·5 | 4801·4 | 4805·2 | 4809·1 | 4812·9 | 4816·8 | 4820·6 | 4824·5 | 4828·3 | 3·8 |

## Table IV.—*continued.*

### A General Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

| v. | 0 | 1· | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 190 | 4 4832·2 | 4836·0 | 4839·8 | 4843·7 | 4847·5 | 4851·4 | 4855·2 | 4859·0 | 4862·8 | 4866·7 | 3·8 |
| 191 | 4870·5 | 4874·3 | 4878·1 | 4882·0 | 4885·8 | 4889·6 | 4893·4 | 4897·3 | 4901·1 | 4904·9 | 3·8 |
| 192 | 4908·7 | 4912·5 | 4916·3 | 4920·1 | 4923·9 | 4927·7 | 4931·5 | 4935·3 | 4939·1 | 4942·9 | 3·8 |
| 193 | 4 4946·7 | 4950·5 | 4954·3 | 4958·1 | 4961·9 | 4965·7 | 4969·4 | 4973·2 | 4977·0 | 4980·7 | 3·8 |
| 194 | 4984·5 | 4988·3 | 4992·1 | 4995·8 | 4999·6 | 5003·4 | 5007·1 | 5010·9 | 5014·7 | 5018·4 | 3·8 |
| 195 | 5022·2 | 5025·9 | 5029·7 | 5033·4 | 5037·2 | 5040·9 | 5044·7 | 5048·4 | 5052·1 | 5055·9 | 3·7 |
| 196 | 4 5059·6 | 5063·4 | 5067·1 | 5070·8 | 5074·6 | 5078·3 | 5082·0 | 5085·7 | 5089·4 | 5093·1 | 3·7 |
| 197 | 5096·9 | 5100·6 | 5104·3 | 5108·0 | 5111·7 | 5115·4 | 5119·1 | 5122·8 | 5126·5 | 5130·2 | 3·7 |
| 198 | 5133·9 | 5137·5 | 5141·2 | 5144·9 | 5148·6 | 5152·3 | 5156·0 | 5159·6 | 5163·3 | 5166·9 | 3·7 |
| 199 | 4 5170·6 | 5174·3 | 5177·9 | 5181·6 | 5185·2 | 5188·9 | 5192·5 | 5196·2 | 5199·8 | 5203·4 | 3·6 |
| 200 | 5207·1 | 5210·7 | 5214·3 | 5218·0 | 5221·6 | 5225·2 | 5228·8 | 5232·5 | 5236·1 | 5239·7 | 3·6 |
| 201 | 5243·3 | 5246·9 | 5250·5 | 5254·1 | 5257·7 | 5261·3 | 5264·9 | 5268·5 | 5272·1 | 5275·7 | 3·6 |
| 202 | 4 5279·2 | 5282·8 | 5286·4 | 5290·0 | 5293·6 | 5297·2 | 5300·7 | 5304·3 | 5307·8 | 5311·4 | 3·6 |
| 203 | 5314·9 | 5318·5 | 5322·0 | 5325·6 | 5329·1 | 5332·7 | 5336·2 | 5339·7 | 5343·3 | 5346·8 | 3·5 |
| 204 | 5350·3 | 5353·8 | 5357·3 | 5360·9 | 5364·4 | 5367·9 | 5371·4 | 5374·9 | 5378·4 | 5381·9 | 3·5 |
| 205 | 4 5385·4 | 5388·9 | 5392·4 | 5395·9 | 5399·4 | 5402·9 | 5406·3 | 5409·8 | 5413·3 | 5416·7 | 3·5 |
| 206 | 5420·2 | 5423·7 | 5427·1 | 5430·6 | 5434·1 | 5437·5 | 5441·0 | 5444·4 | 5447·8 | 5451·3 | 3·5 |
| 207 | 5454·7 | 5458·1 | 5461·6 | 5465·0 | 5468·4 | 5471·9 | 5475·3 | 5478·7 | 5482·1 | 5485·5 | 3·4 |
| 208 | 4 5488·9 | 5492·3 | 5495·7 | 5499·1 | 5502·5 | 5505·9 | 5509·3 | 5512·7 | 5516·1 | 5519·4 | 3·4 |
| 209 | 5522·8 | 5526·2 | 5529·6 | 5532·9 | 5536·3 | 5539·7 | 5543·0 | 5546·4 | 5549·7 | 5553·1 | 3·4 |
| 210 | 5556·4 | 5559·8 | 5563·1 | 5566·4 | 5569·8 | 5573·1 | 5576·5 | 5579·8 | 5583·1 | 5586·4 | 3·3 |
| 211 | 4 5589·7 | 5593·0 | 5596·4 | 5599·7 | 5603·0 | 5606·3 | 5609·6 | 5612·9 | 5616·2 | 5619·5 | 3·3 |
| 212 | 5622·8 | 5626·1 | 5629·3 | 5632·6 | 5635·9 | 5639·2 | 5642·5 | 5645·7 | 5649·0 | 5652·3 | 3·3 |
| 213 | 5655·5 | 5658·8 | 5662·0 | 5665·3 | 5668·6 | 5671·8 | 5675·1 | 5678·3 | 5681·5 | 5684·8 | 3·2 |
| 214 | 4 5688·0 | 5691·2 | 5694·5 | 5697·7 | 5700·9 | 5704·2 | 5707·4 | 5710·6 | 5713·8 | 5717·0 | 3·2 |
| 215 | 5720·2 | 5723·4 | 5726·6 | 5729·9 | 5733·1 | 5736·3 | 5739·5 | 5742·6 | 5745·8 | 5749·0 | 3·2 |
| 216 | 5752·2 | 5755·4 | 5758·6 | 5761·8 | 5764·9 | 5768·1 | 5771·3 | 5774·4 | 5777·6 | 5780·8 | 3·2 |
| 217 | 4 5783·9 | 5787·1 | 5790·2 | 5793·4 | 5796·6 | 5799·7 | 5802·9 | 5806·0 | 5809·1 | 5812·2 | 3·1 |
| 218 | 5815·4 | 5818·5 | 5821·6 | 5824·8 | 5827·9 | 5831·0 | 5834·1 | 5837·3 | 5840·4 | 5843·5 | 3·1 |
| 219 | 5846·6 | 5849·7 | 5852·8 | 5855·9 | 5859·0 | 5862·1 | 5865·2 | 5868·3 | 5871·4 | 5874·4 | 3·1 |
| 220 | 4 5877·5 | 5880·6 | 5883·7 | 5886·8 | 5889·9 | 5893·0 | 5896·0 | 5899·1 | 5902·1 | 5905·2 | 3·1 |
| 221 | 5908·3 | 5911·3 | 5914·4 | 5917·4 | 5920·5 | 5923·6 | 5926·6 | 5929·6 | 5932·7 | 5935·7 | 3·0 |
| 222 | 5938·7 | 5941·8 | 5944·8 | 5947·8 | 5950·9 | 5953·9 | 5956·9 | 5959·9 | 5963·0 | 5966·0 | 3·0 |
| 223 | 4 5969·0 | 5972·0 | 5975·0 | 5978·0 | 5981·0 | 5984·0 | 5987·0 | 5990·0 | 5993·0 | 5996·0 | 3·0 |
| 224 | 5999·0 | 6002·0 | 6004·9 | 6007·9 | 6010·9 | 6013·9 | 6016·9 | 6019·8 | 6022·8 | 6025·8 | 3·0 |
| 225 | 6028·7 | 6031·7 | 6034·6 | 6037·6 | 6040·5 | 6043·5 | 6046·5 | 6049·4 | 6052·4 | 6055·3 | 3·0 |
| 226 | 4 6058·3 | 6061·2 | 6064·1 | 6067·1 | 6070·0 | 6072·9 | 6075·9 | 6078·8 | 6081·7 | 6084·7 | 2·9 |
| 227 | 6087·6 | 6090·5 | 6093·4 | 6096·3 | 6099·3 | 6102·2 | 6105·1 | 6108·0 | 6110·9 | 6113·8 | 2·9 |
| 228 | 6116·7 | 6119·6 | 6122·5 | 6125·4 | 6128·3 | 6131·2 | 6134·1 | 6137·0 | 6139·9 | 6142·8 | 2·9 |
| 229 | 4 6145·7 | 6148·6 | 6151·5 | 6154·4 | 6157·3 | 6160·2 | 6163·1 | 6166·0 | 6168·8 | 6171·7 | 2·9 |
| 230 | 6174·6 | 6177·5 | 6180·4 | 6183·3 | 6186·2 | 6189·1 | 6191·9 | 6194·8 | 6197·7 | 6200·6 | 2·9 |
| 231 | 6203·5 | 6206·4 | 6209·3 | 6212·1 | 6215·0 | 6217·9 | 6220·8 | 6223·7 | 6226·6 | 6229·5 | 2·9 |
| 232 | 4 6232·3 | 6235·2 | 6238·1 | 6241·0 | 6243·9 | 6246·8 | 6249·7 | 6252·6 | 6255·4 | 6258·3 | 2·9 |
| 233 | 6261·2 | 6264·1 | 6267·0 | 6269·9 | 6272·8 | 6275·7 | 6278·6 | 6281·5 | 6284·3 | 6287·2 | 2·9 |
| 234 | 6290·1 | 6293·0 | 6295·9 | 6298·8 | 6301·7 | 6304·6 | 6307·5 | 6310·4 | 6313·3 | 6316·2 | 2·9 |
| 235 | 4 6319·0 | 6322·0 | 6324·9 | 6327·7 | 6330·6 | 6333·5 | 6336·4 | 6339·3 | 6342·2 | 6345·1 | 2·9 |
| 236 | 6348·0 | 6350·9 | 6353·8 | 6356·7 | 6359·6 | 6362·5 | 6365·4 | 6368·3 | 6371·2 | 6374·1 | 2·9 |
| 237 | 6377·0 | 6379·9 | 6382·8 | 6385·7 | 6388·6 | 6391·5 | 6394·4 | 6397·3 | 6400·2 | 6403·1 | 2·9 |
| 238 | 4 6406·0 | 6408·9 | 6411·8 | 6414·8 | 6417·7 | 6420·6 | 6423·5 | 6426·4 | 6429·3 | 6432·2 | 2·9 |
| 239 | 6435·1 | 6438·0 | 6440·9 | 6443·8 | 6446·8 | 6449·7 | 6452·6 | 6455·5 | 6458·4 | 6461·3 | 2·9 |
| 240 | 6464·2 | 6467·1 | 6470·1 | 6473·0 | 6475·9 | 6478·8 | 6481·7 | 6484·6 | 6487·6 | 6490·5 | 2·9 |
| 241 | 4 6493·4 | 6496·3 | 6499·2 | 6502·2 | 6505·1 | 6508·0 | 6510·9 | 6513·8 | 6516·8 | 6519·7 | 2·9 |
| 242 | 6522·6 | 6525·6 | 6528·5 | 6531·4 | 6534·3 | 6537·3 | 6540·2 | 6543·1 | 6546·2 | 6549·0 | 2·9 |
| 243 | 6551·9 | 6554·9 | 6557·8 | 6560·7 | 6563·7 | 6566·6 | 6569·5 | 6572·5 | 6575·4 | 6578·3 | 2·9 |
| 244 | 4 6581·3 | 6584·2 | 6587·2 | 6590·1 | 6593·0 | 6596·0 | 6598·9 | 6601·8 | 6604·8 | 6607·7 | 2·9 |
| 245 | 6610·6 | 6613·6 | 6616·5 | 6619·5 | 6622·4 | 6625·3 | 6628·3 | 6631·2 | 6634·2 | 6637·1 | 2·9 |
| 246 | 6640·1 | 6643·0 | 6645·9 | 6648·9 | 6651·8 | 6654·8 | 6657·7 | 6660·6 | 6663·6 | 6666·5 | 2·9 |
| 247 | 4 6669·5 | 6672·4 | 6675·4 | 6678·3 | 6681·3 | 6684·2 | 6687·2 | 6690·1 | 6693·0 | 6696·0 | 2·9 |
| 248 | 6698·9 | 6701·9 | 6704·8 | 6707·8 | 6710·7 | 6713·7 | 6716·6 | 6719·6 | 6722·5 | 6725·5 | 2·9 |
| 249 | 6728·4 | 6731·3 | 6734·3 | 6737·2 | 6740·2 | 6743·1 | 6746·1 | 6749·0 | 6752·0 | 6754·9 | 2·9 |

## Table IV.—*continued.*

## A General Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

| v. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 250 | 4 6757·8 | 6760·7 | 6763·7 | 6766·7 | 6769·6 | 6772·6 | 6775·5 | 6778·4 | 6781·4 | 6784·3 | 2·9 |
| 251 | 6787·3 | 6790·2 | 6793·1 | 6796·1 | 6799·0 | 6802·0 | 6804·9 | 6807·8 | 6810·8 | 6813·7 | 2·9 |
| 252 | 6816·6 | 6819·6 | 6822·5 | 6825·4 | 6828·4 | 6831·3 | 6834·2 | 6837·1 | 6840·1 | 6843·0 | 2·9 |
| 253 | 4 6845·9 | 6848·8 | 6851·8 | 6854·7 | 6857·6 | 6860·5 | 6863·5 | 6866·4 | 6869·3 | 6872·2 | 2·9 |
| 254 | 6875·1 | 6878·1 | 6881·0 | 6883·9 | 6886·8 | 6889·7 | 6892·6 | 6895·6 | 6898·5 | 6901·4 | 2·9 |
| 255 | 6904·3 | 6907·2 | 6910·1 | 6915·0 | 6915·9 | 6918·8 | 6921·7 | 6924·6 | 6927·5 | 6930·4 | 2·9 |
| 256 | 4 6933·3 | 6936·2 | 6939·1 | 6942·0 | 6944·9 | 6947·8 | 6950·6 | 6953·5 | 6956·4 | 6959·3 | 2·9 |
| 257 | 6962·2 | 6965·0 | 6967·9 | 6970·8 | 6973·7 | 6976·5 | 6979·4 | 6982·3 | 6985·1 | 6988·0 | 2·9 |
| 258 | 6990·9 | 6993·7 | 6996·6 | 6999·4 | 7002·3 | 7005·1 | 7008·0 | 7010·8 | 7013·7 | 7016·5 | 2·9 |
| 259 | 4 7019·4 | 7022·2 | 7025·0 | 7027·9 | 7030·7 | 7033·5 | 7036·4 | 7039·2 | 7042·0 | 7044·8 | 2·8 |
| 260 | 7047·7 | 7050·5 | 7053·3 | 7056·1 | 7058·9 | 7061·7 | 7064·5 | 7067·4 | 7070·2 | 7073·0 | 2·8 |
| 261 | 7075·8 | 7078·6 | 7081·4 | 7084·2 | 7087·0 | 7089·7 | 7092·5 | 7095·3 | 7098·1 | 7100·9 | 2·8 |
| 262 | 4 7103·7 | 7106·5 | 7109·2 | 7112·0 | 7114·8 | 7117·6 | 7120·3 | 7123·1 | 7125·9 | 7128·6 | 2·8 |
| 263 | 7131·4 | 7134·2 | 7136·9 | 7139·7 | 7142·4 | 7145·2 | 7147·9 | 7150·7 | 7153·4 | 7156·2 | 2·8 |
| 264 | 7158·9 | 7161·7 | 7164·4 | 7167·1 | 7169·9 | 7172·6 | 7175·4 | 7178·1 | 7180·8 | 7183·5 | 2·7 |
| 265 | 4 7186·3 | 7189·0 | 7191·7 | 7194·4 | 7197·1 | 7199·9 | 7202·6 | 7205·3 | 7208·0 | 7210·7 | 2·7 |
| 266 | 7213·4 | 7216·1 | 7218·8 | 7221·5 | 7224·2 | 7226·9 | 7229·6 | 7232·3 | 7235·0 | 7237·7 | 2·7 |
| 267 | 7240·4 | 7243·1 | 7245·8 | 7248·5 | 7251·2 | 7253·8 | 7256·5 | 7259·2 | 7261·9 | 7264·5 | 2·7 |
| 268 | 4 7267·2 | 7269·9 | 7272·5 | 7275·2 | 7277·9 | 7280·5 | 7283·2 | 7285·9 | 7288·5 | 7291·2 | 2·7 |
| 269 | 7293·8 | 7296·5 | 7299·1 | 7301·8 | 7304·4 | 7307·1 | 7309·7 | 7312·3 | 7315·0 | 7317·6 | 2·6 |
| 270 | 7320·2 | 7322·9 | 7325·5 | 7328·1 | 7330·8 | 7333·4 | 7336·0 | 7338·6 | 7341·2 | 7343·9 | 2·6 |
| 271 | 4 7346·5 | 7349·1 | 7351·7 | 7354·3 | 7356·9 | 7359·5 | 7362·1 | 7364·7 | 7367·3 | 7369·9 | 2·6 |
| 272 | 7372·5 | 7375·1 | 7377·7 | 7380·3 | 7382·9 | 7385·5 | 7388·1 | 7390·7 | 7393·3 | 7395·8 | 2·6 |
| 273 | 7398·4 | 7401·0 | 7403·6 | 7406·2 | 7408·7 | 7411·3 | 7413·9 | 7416·4 | 7419·0 | 7421·6 | 2·6 |
| 274 | 4 7424·1 | 7426·7 | 7429·3 | 7431·8 | 7434·4 | 7436·9 | 7439·5 | 7442·0 | 7444·6 | 7447·1 | 2·6 |
| 275 | 7449·7 | 7452·2 | 7454·8 | 7457·3 | 7459·8 | 7462·4 | 7464·9 | 7467·4 | 7470·0 | 7472·5 | 2·5 |
| 276 | 7475·0 | 7477·5 | 7480·1 | 7482·6 | 7485·1 | 7487·6 | 7490·1 | 7492·7 | 7495·2 | 7497·7 | 2·5 |
| 277 | 4 7500·2 | 7502·7 | 7505·2 | 7507·7 | 7510·2 | 7512·7 | 7515·2 | 7517·7 | 7520·2 | 7522·7 | 2·5 |
| 278 | 7525·2 | 7527·7 | 7530·1 | 7532·6 | 7535·1 | 7537·6 | 7540·1 | 7542·6 | 7545·0 | 7547·5 | 2·5 |
| 279 | 7550·0 | 7552·4 | 7554·9 | 7557·4 | 7559·9 | 7562·3 | 7564·8 | 7567·2 | 7569·7 | 7572·2 | 2·5 |
| 280 | 4 7574·6 | 7577·1 | 7579·5 | 7582·0 | 7584·4 | 7586·8 | 7589·3 | 7591·7 | 7594·2 | 7596·6 | 2·4 |
| 281 | 7599·0 | 7601·5 | 7603·9 | 7606·4 | 7608·8 | 7611·2 | 7613·6 | 7616·1 | 7618·5 | 7620·9 | 2·4 |
| 282 | 7623·3 | 7625·7 | 7628·2 | 7630·6 | 7633·0 | 7635·4 | 7637·8 | 7640·2 | 7642·6 | 7645·0 | 2·4 |
| 283 | 4 7647·4 | 7649·8 | 7652·2 | 7654·6 | 7657·0 | 7659·4 | 7661·8 | 7664·2 | 7666·6 | 7669·0 | 2·4 |
| 284 | 7671·3 | 7673·7 | 7676·1 | 7678·5 | 7680·9 | 7683·3 | 7685·6 | 7688·0 | 7690·4 | 7692·7 | 2·4 |
| 285 | 7695·1 | 7697·5 | 7699·8 | 7702·2 | 7704·6 | 7706·9 | 7709·3 | 7711·6 | 7714·0 | 7716·4 | 2·4 |
| 286 | 4 7718·7 | 7721·1 | 7723·4 | 7725·8 | 7728·1 | 7730·4 | 7732·8 | 7735·1 | 7737·5 | 7739·8 | 2·3 |
| 287 | 7742·1 | 7744·5 | 7746·8 | 7749·1 | 7751·5 | 7753·8 | 7756·1 | 7758·4 | 7760·8 | 7763·1 | 2·3 |
| 288 | 7765·4 | 7767·7 | 7770·0 | 7772·4 | 7774·7 | 7777·0 | 7779·3 | 7781·6 | 7783·9 | 7786·2 | 2·3 |
| 289 | 4 7788·5 | 7790·8 | 7793·1 | 7795·4 | 7797·7 | 7800·0 | 7802·3 | 7804·6 | 7806·9 | 7809·2 | 2·3 |
| 290 | 7811·5 | | | | | | | | | | |

# INDEX.

## A.

## B.

## C.

## D.

## E.

## F.

## G.

## H.



## I.

## Q.

## S.

## T.

PAGE



## U.



## V.

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